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1960

Vol 3

Nos. 19 to 30

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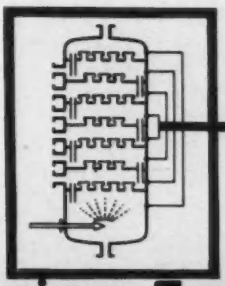

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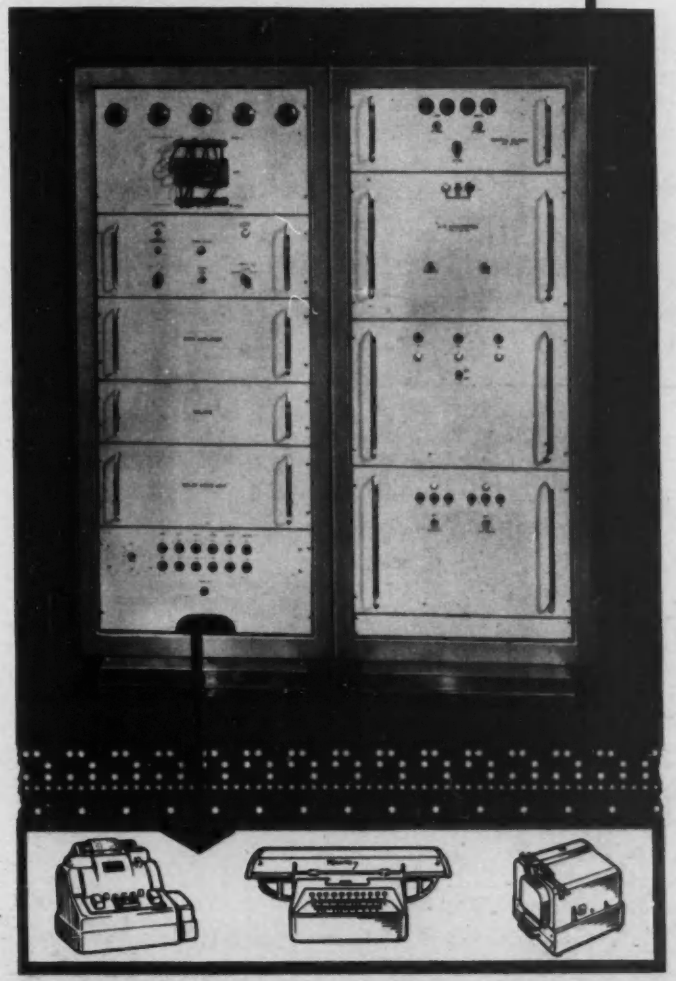

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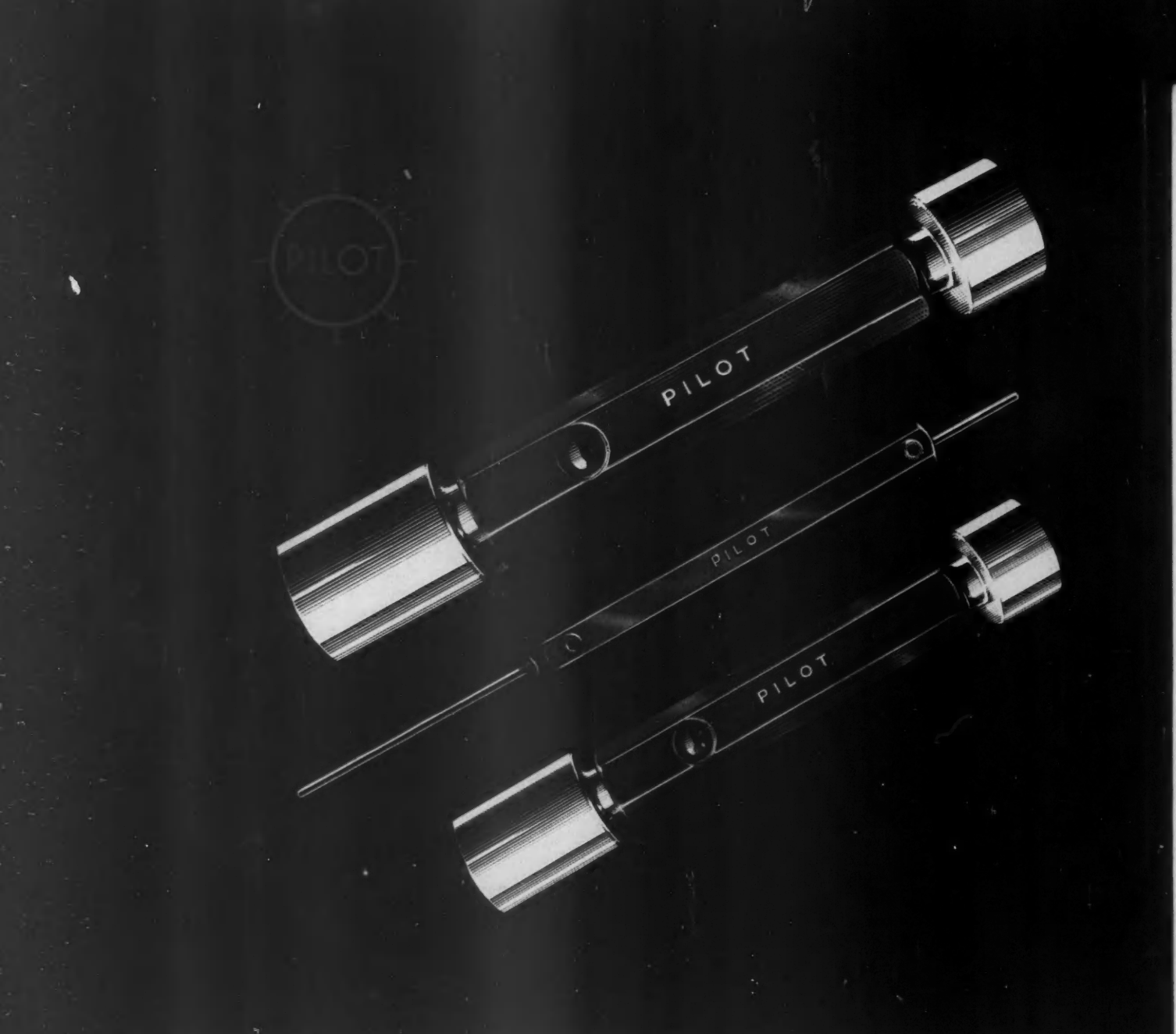

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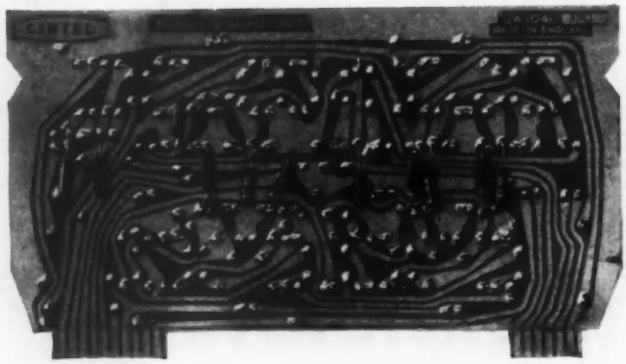

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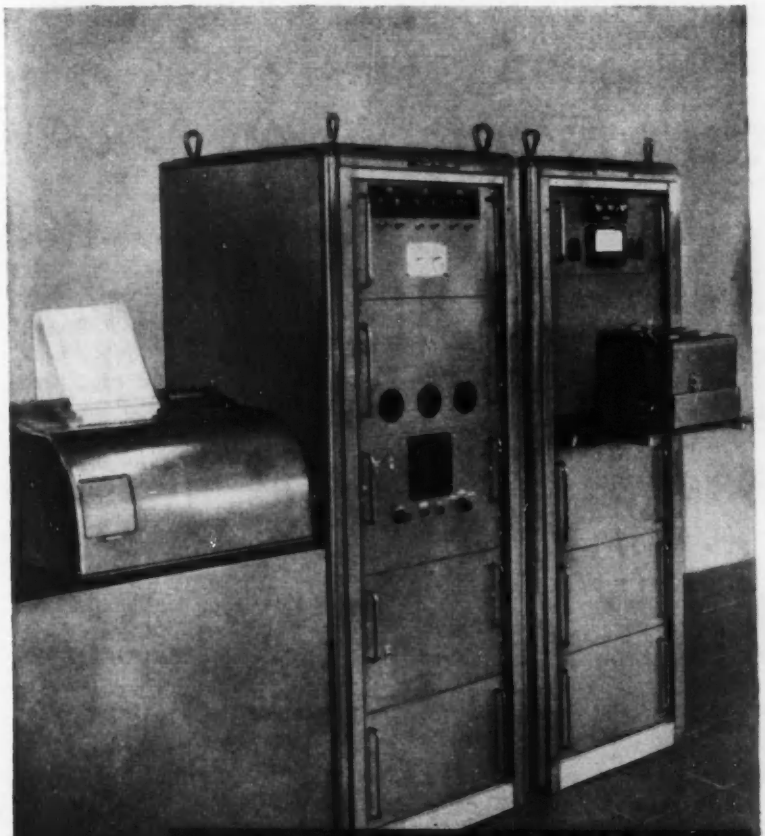

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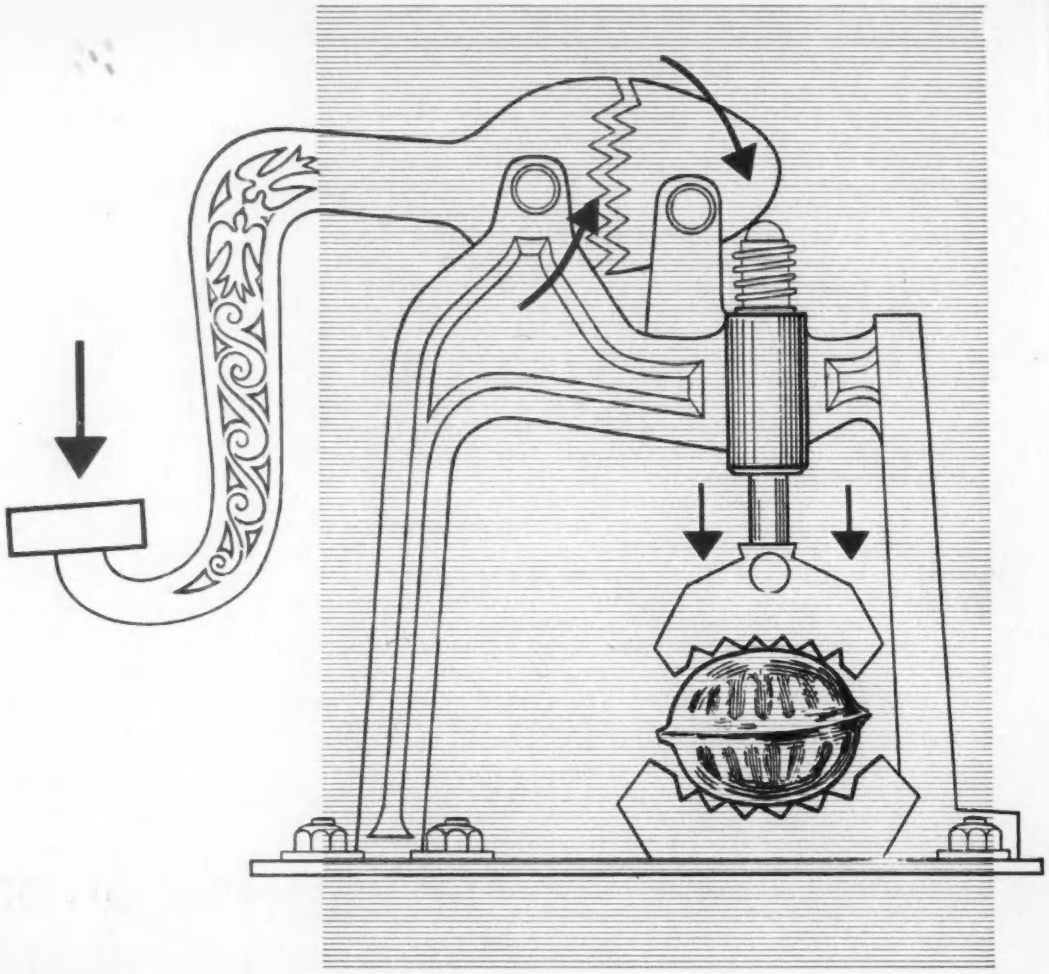

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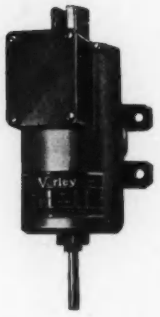

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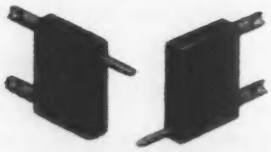

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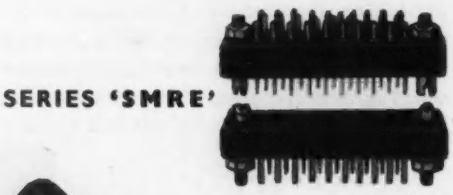

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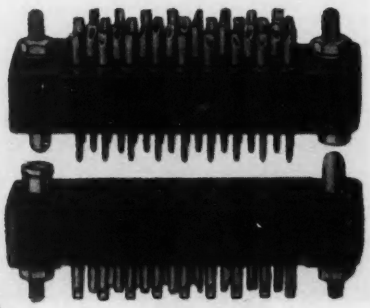

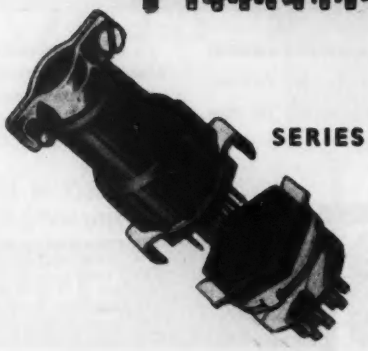

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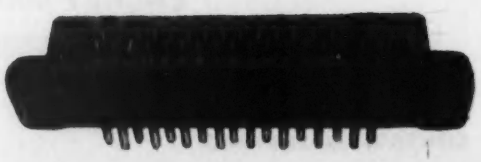

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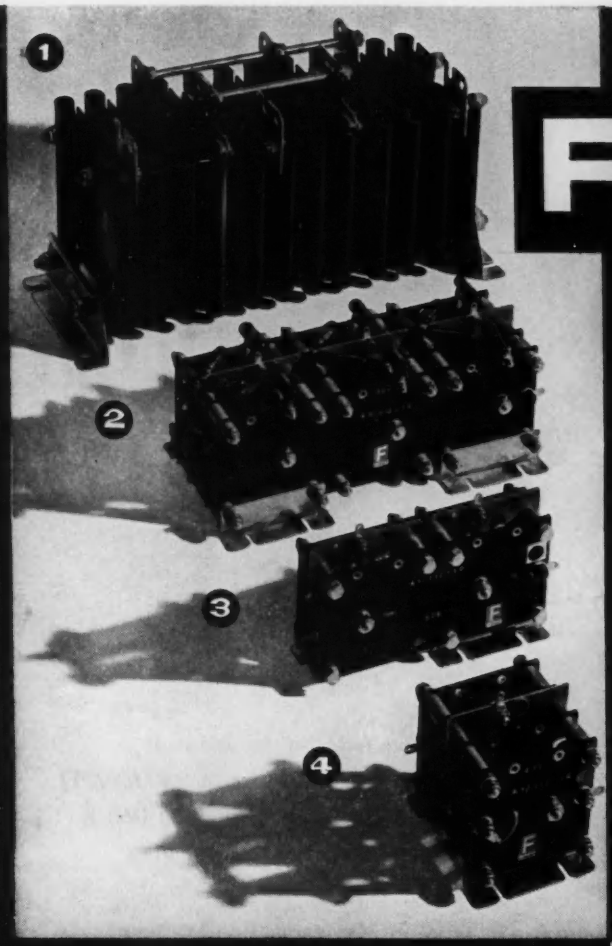

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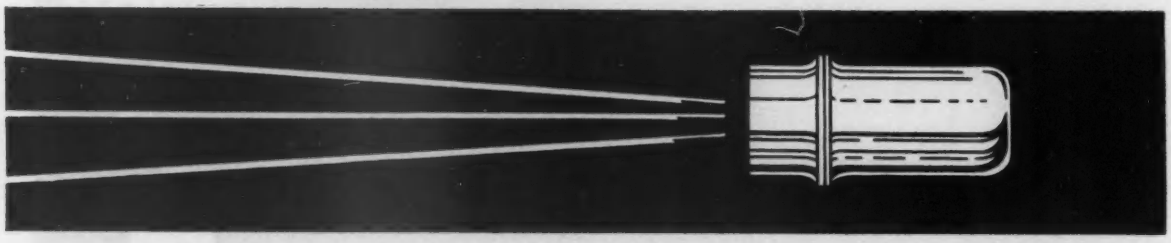

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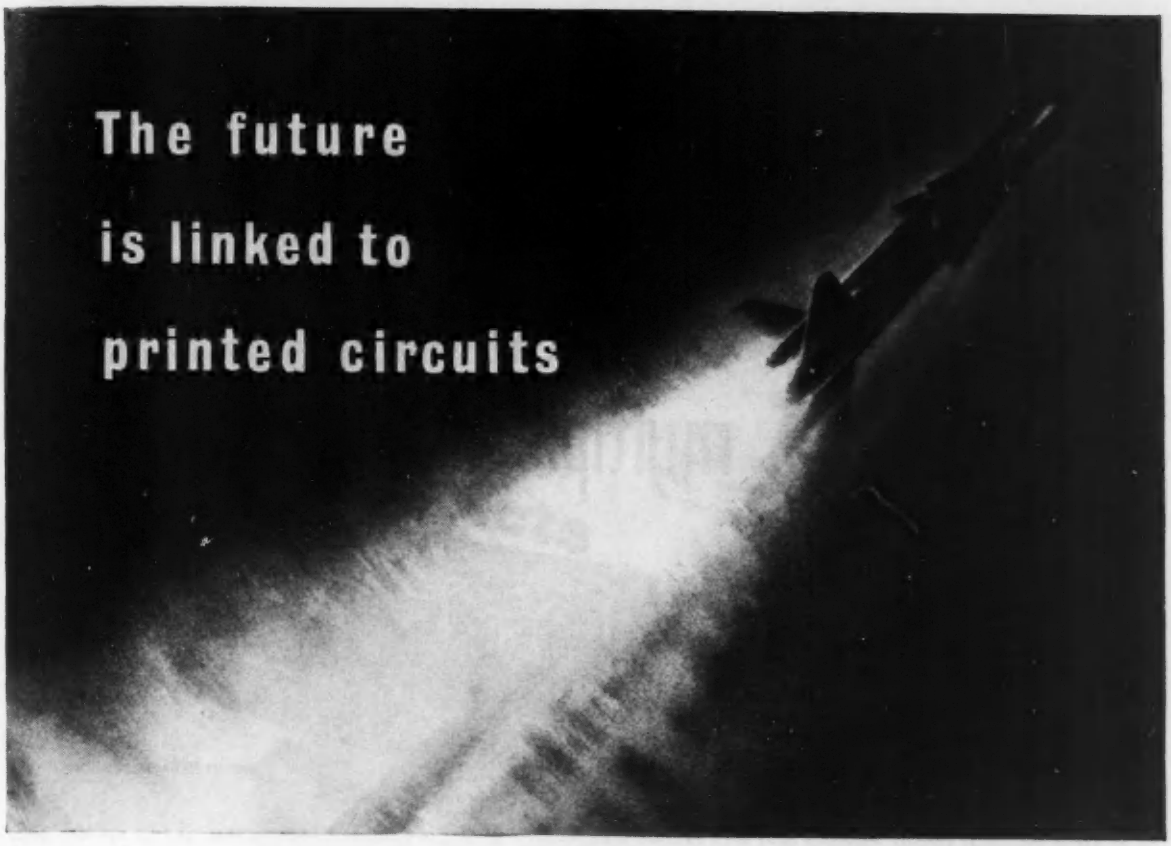

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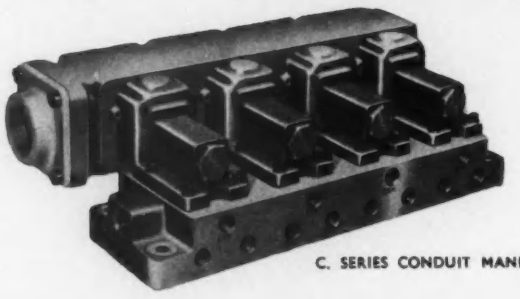

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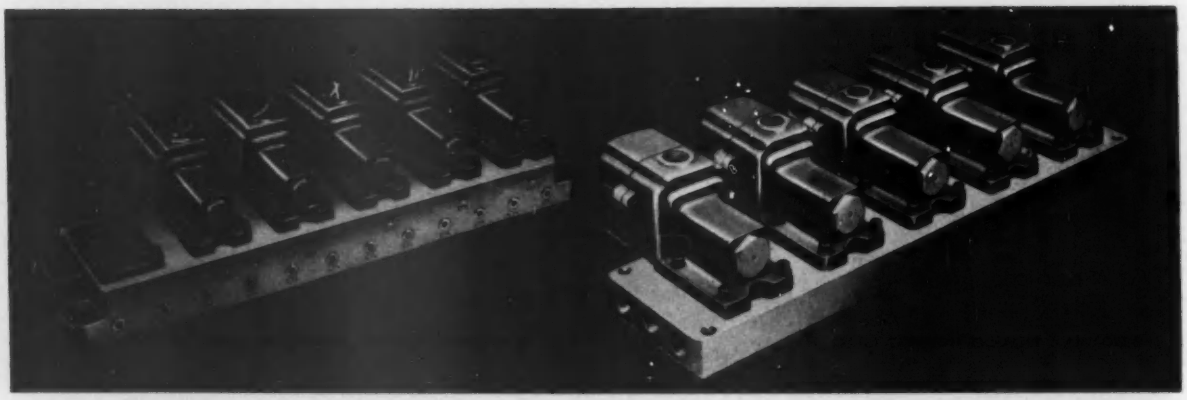

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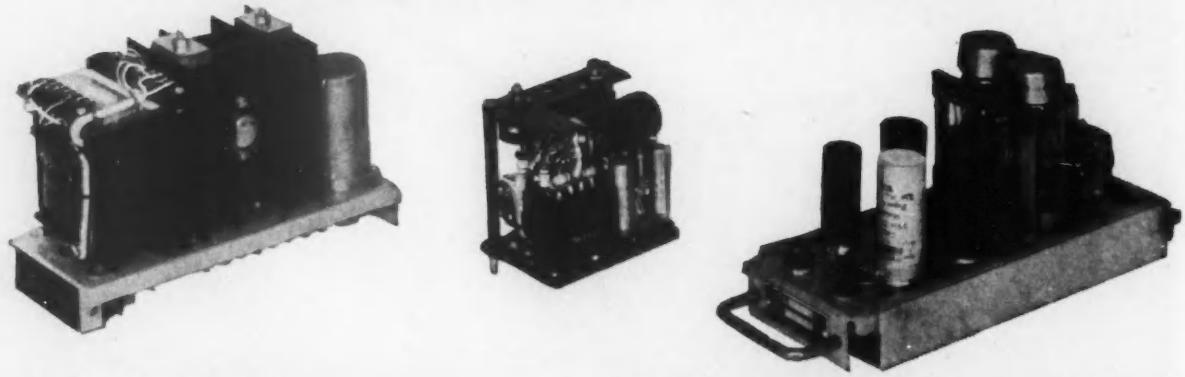

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Another New TRANSITROL'!

TYPE 995

CONTINUOUSLY-ACTING PROPORTIONAL TEMPERATURE-CONTROLLER with manual reset

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** Precision control * Low maintenance*
** 7-in. indicating scale*

This new ETHER TRANSITROL Type 995 Controller operates in conjunction with a proportioning valve. It offers continuously-acting proportional control, to very close accuracy, on gas or oil-firing applications and maintains steam at a constant pressure under varying loads.

Proportional control is also available with the ETHER TRANSITROL Programme Temperature-Controller which indicates and controls temperature to a pre-determined time programme.

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COMPUTER EXHIBITION PREVIEW
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VOLUME 1 NUMBER 5
MONTHLY 3/6
CONTROL
PLEASE CIRCULATE TO :

Mr. Davis is scheduled to be a bit behind

For three weeks *Control* lay buried on Mr. Brown's desk.

Then Mr. Smithson became interested in a treatise on two-group theory that he never actually got round to. That took fourteen days.

Now the *real* readers will be in possession for months. Mr. McDuff, here, has spilt coffee on page 22 and abstracted some graphs that specially caught his eye on page 29.

By the time our magazine reaches Mr. Davis it won't be what it was. Pity—because of all these people Mr. Davis is potentially the most brilliant. The sooner he fills in the pre-paid subscription card facing page 150 the better. After all, a personal copy of *Control* costs only 3/6 a month.

Relays that latch magnetically and hold without power

We call them REMANENT RELAYS. They make obsolete the use of hold-on coils and contacts and are eminently suitable for DIGIT STORE and REMOTE CONTROL applications. Fitted with cores having a high retentivity rating, they latch-up on receipt of a signal and remain so without power, until the core flux is cancelled. *Two versions—types 3,000 and 600. Fitted with a variety of coil windings and contact assemblies.* We shall be glad to give you full specification details.

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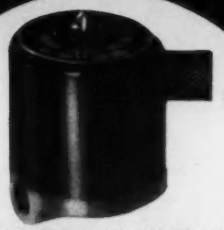

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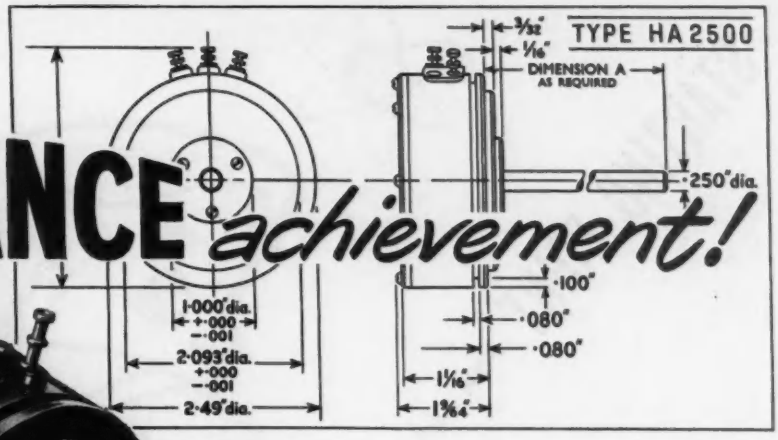

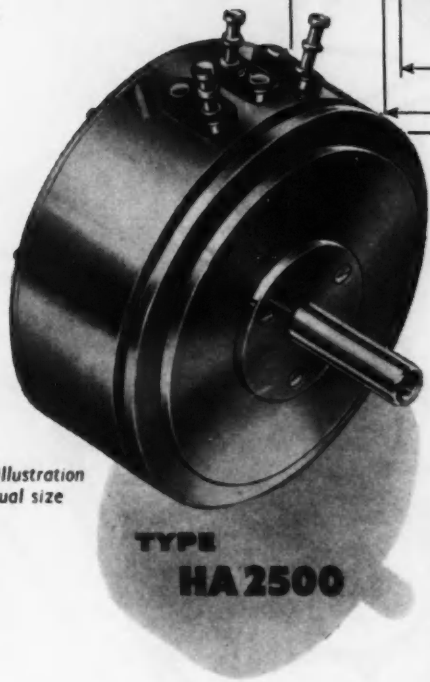

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HIGH LAW ACCURACY
without cam correction

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Law Accuracy (Absolute)	± 0.25% or ± 0.10%
(Independent law accuracy to closer limits)	
Maximum Starting Torque	1 oz/in.
Maximum Ganged Sections	Four.
Maximum Tappings	Nine.

Full technical details and dimensional drawings in Data Sheet No. 100 available on request.

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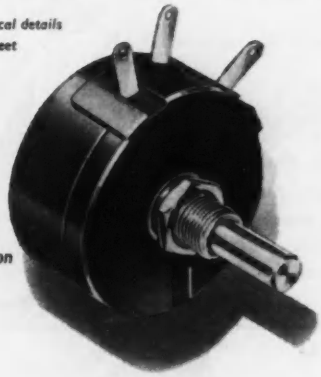
. . . ***and*** ANOTHER ADDITION TO THE COMPREHENSIVE RELIANCE RANGE

The **TYPE W3** (3 WATT)

This model conforms with specification DEF-5121 style RVW 7 & 8 (formerly RAC.RAD) and is a fully sealed unit with integrally constructed moulded cover. Also available in unsealed version.

Full technical details in Data Sheet No. 9



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GD.60

STARTING POINT FOR AUTOMATION PLANNING

If you are concerned in any way with Automation Planning, make sure you have a copy of the new Amphenol Publication IEC2. Profusely illustrated in colour, this new book details a wide range of suitable Amphenol Connectors, includes reference sheets for contact arrangements and insert specifications. Write for your copy now.

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Quick-disconnect, multi-contact, miniature bayonet lock types. Available as Plugs, Cable and Panel Receptacles in 4 constructions, 5 shell sizes and 17 insert arrangements.

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Glasgow: 13 Queen Street, Glasgow, C.1. City 3202

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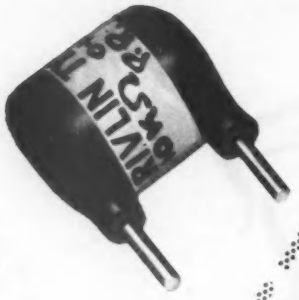
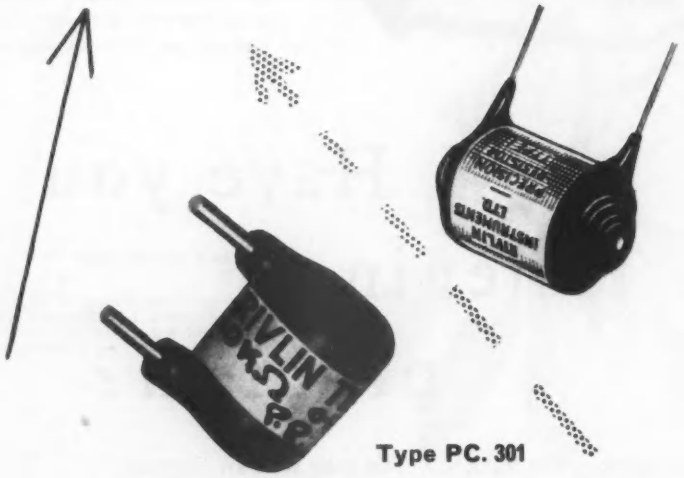


Type 201

Type 201, the newest precision wirewound resistor can be plugged into an Electro Methods type D2 socket. Gold-plated phosphor bronze pins ensure strength with consistent low ohmic contact resistance, while the tough resin encapsulation will withstand extremes of temperature and humidity.

RIVLIN

for high precision resistors



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The standard range of Rivlin precision resistors are eminently suited to all applications requiring great accuracy, stability and low temperature coeffecient. Supplied to any tolerance up to ± 0.1% of the nominal value, or 0.01Ω, whichever is greater.

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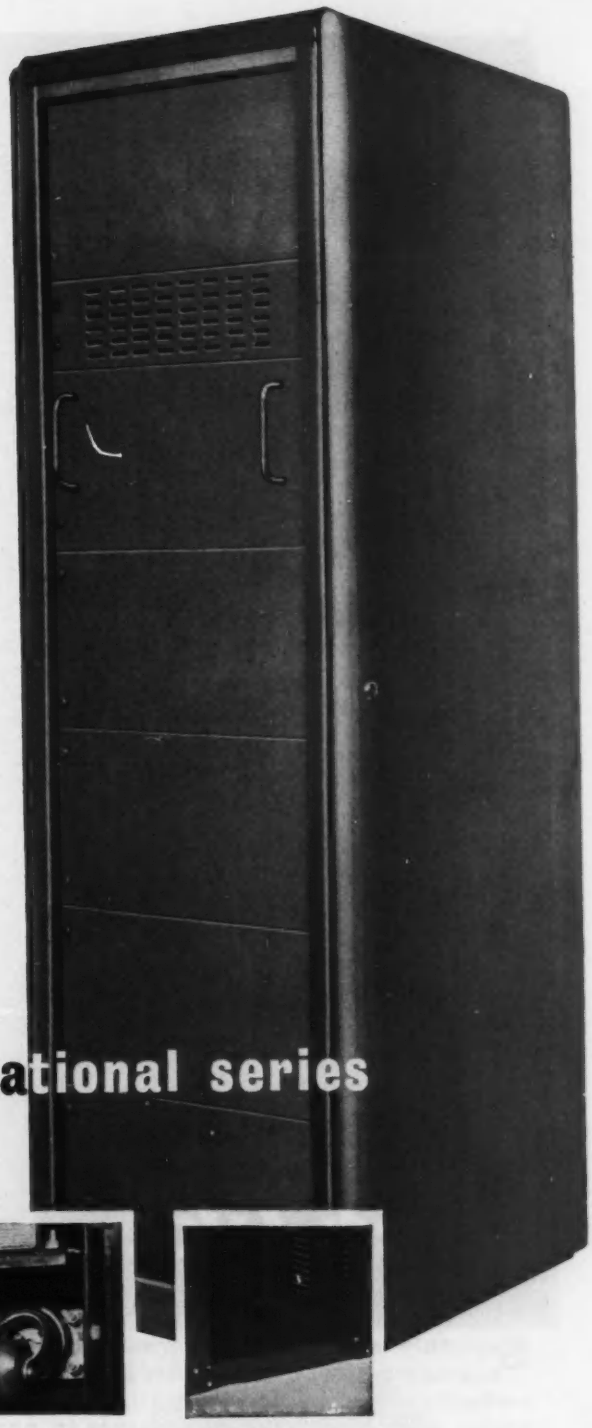
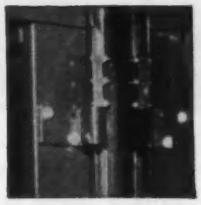
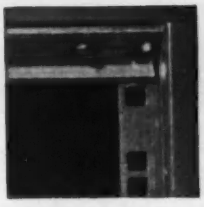
Imhofs new, modular Imrak series fills an outstanding need for a completely universal and flexible rack system. The new IMRAK International Rak is easily adapted for sealing, ventilating, moving or baying-up. It can carry British, American and Continental fixings. It packs flat for easy storage or transportation. Infinitely adjustable inside frames are available which, with four plan sizes, give maximum flexibility. There is a choice of normal front panels, one-piece front panel or recessed front panels with removable door. Panels can also be fitted at the rear. Side doors, too, are removable. A range of heights is available. The new International Rak is made in any of five standard finishes on very quick delivery. Other finishes to special order. Send for full literature



NEW imrak international series



1 The strong, concealed lift-off hinges, of patented design, on the side doors



2 The quick-release mechanism allowing the rear door to be lifted easily off its hinges

3 Provision for fitting castors, obviating the need for mobile bases

4 Pre-punched holes permitting speedy, accurate baying-up

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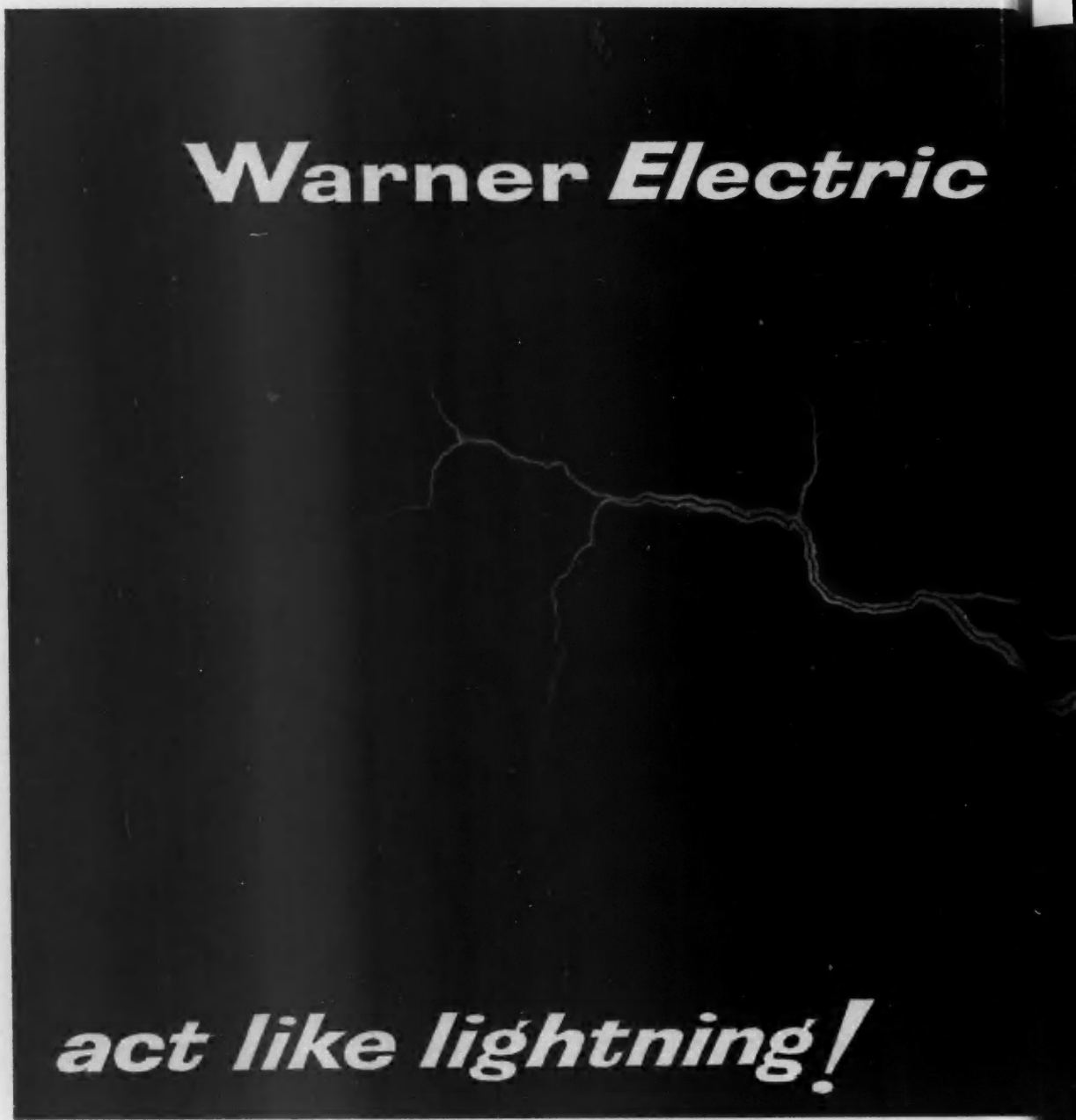
Warner *Electric*



act like lightning!

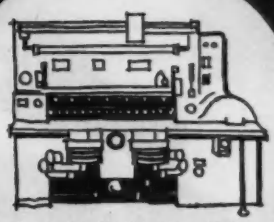
Smoothly and rapidly, Warner Electric Brakes and Clutches are taking push-button control of Britain's industry. These control units —standard equipment in machine shops of the U.S.A.—point the electronic way to major improvements in numerous types of machines.

Immediate advantages. Versatile, compact, ***instantaneous*** in response, Warner units solve starting and stopping problems effectively and economically. Furthermore, they have been completely successful on applications controlling speed, tensioning, positioning, coupling, indexing and rapid cycling. They can be fitted to existing machines; they enable new machines to be smaller, faster and easier to operate.

Take the quickest step to increase your production—ask today about Warner units. Full technical advice is always available.

TAKE THE LEAD

brakes & clutches



Furnival guillotine controlled electrically by Warner Brakes and Clutches

This high speed carpet spinning machine is controlled by a Warner 1000 Electric Clutch

Warner Electric Brakes and Clutches are manufactured in Great Britain under licence by:

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TIB/124

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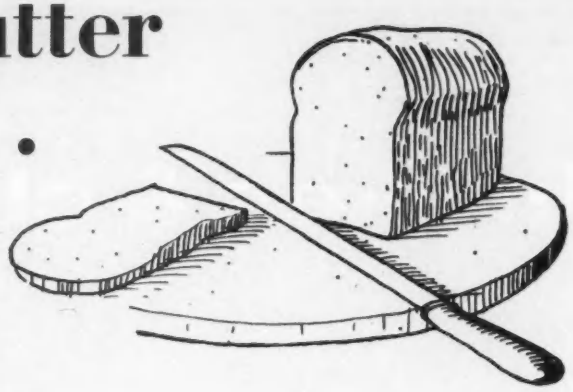
Bread and butter business . . .



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Strength in relation to size, insulation properties, drilling and tapping propensities, all have to be provided for and in materials ranging from vulcanized fibre to glass fibre.

Washers, grommetts, studs, pins, bushes, spacers, rollers, non-metallic bolts and nuts, all are in demand. Take a typewriter, a washing machine, a clock, an adding machine, and a hundred and one other articles in daily use, and sure enough you will find some Delanco part doing whatever is required of it efficiently—thanks to the technical know-how allied to the latest machining techniques and years of experience.

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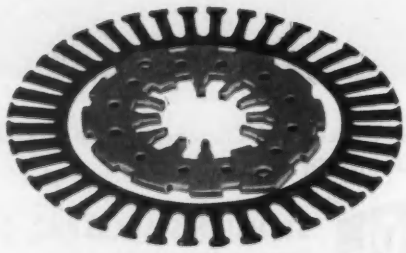

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Use this technical advisory service

Kelvin Hughes specialists are available to advise on the suitability of these components for specific applications, and consultation at preliminary design stage will prove advantageous.

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Absolute or Differential types are available in a wide range of sizes in phosphor-bronze or beryllium-copper. Also arc-welded types in Ni-Span 'C', Monel, K-Monel, Inconel and many stainless steels. These special types can overcome the various limitations of traditional copper-alloy capsules and technical advice on the best possible use of these is obtainable on request.

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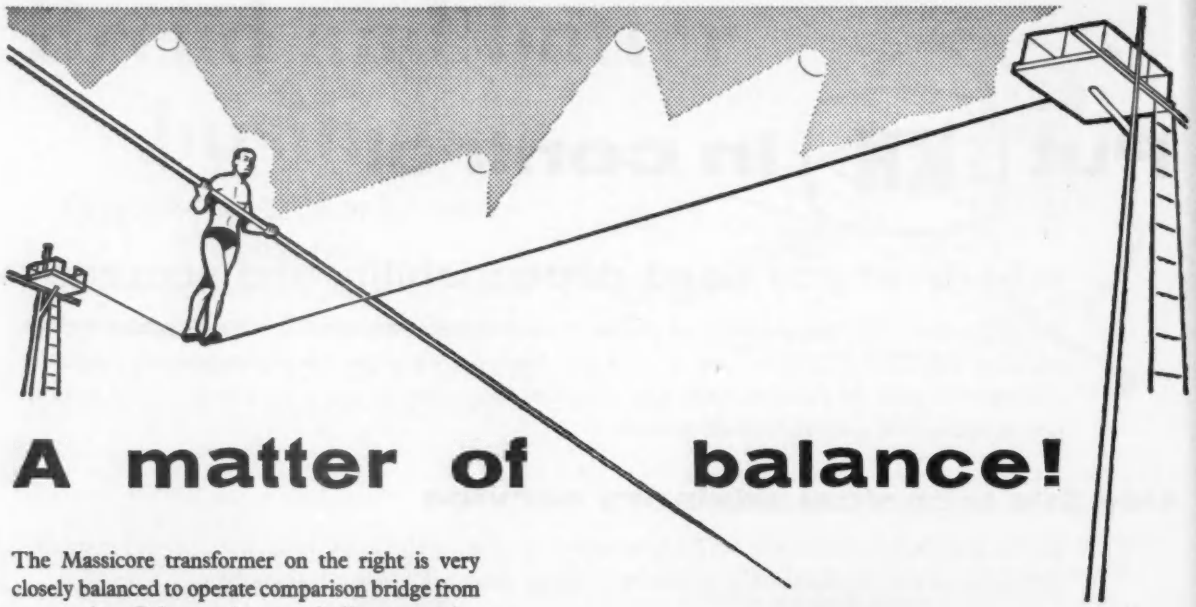
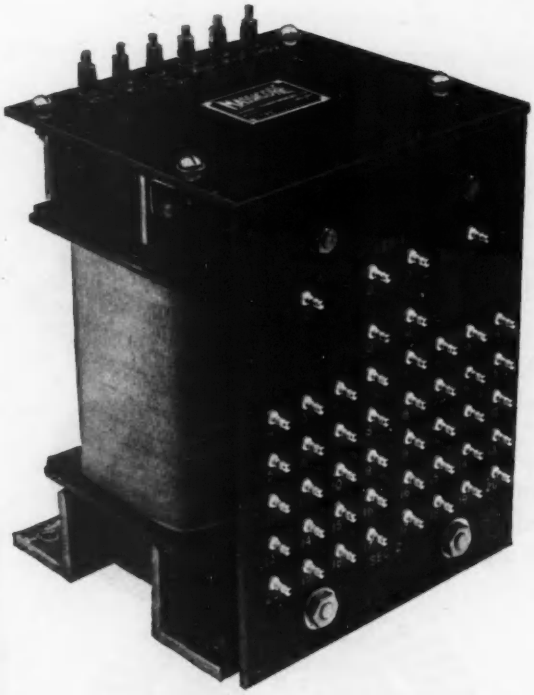


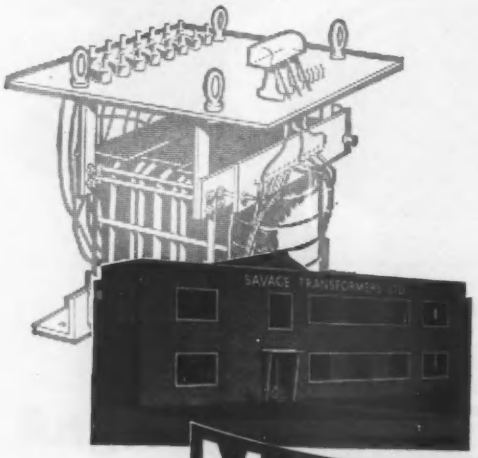
A matter of balance!

The Massicore transformer on the right is very closely balanced to operate comparison bridge from 50~ mains. Primary electrostatically screened—200/250v. 50~ Secondaries. Two 40v. centre-tapped windings one also tapped every volt. Loads 200Ω to 1,000Ω.

PHASE SHIFT PRI/SEC. 20 MINUTES MAX. SEC./SEC. 10 MINUTES MAX. TAPPED AND UNTAPPED SECONDARIES TO BE IDENTICAL AS TO LEAKAGE REACTANCE, D.C. RESISTANCE AND CAPACITY AND BALANCED WITHIN 0.1% ABOUT THEIR CENTRE TAPS. NO VOLTAGE TO DIFFER BY MORE THAN 0.4% OF NOMINAL FROM NO LOAD TO FULL LOAD.

We have had over a quarter of a century's experience designing and building transformers for unusual applications such as this.





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THE LITTLE FACTORY WITH THE BIG REPUTATION

SAVAGE TRANSFORMERS LIMITED
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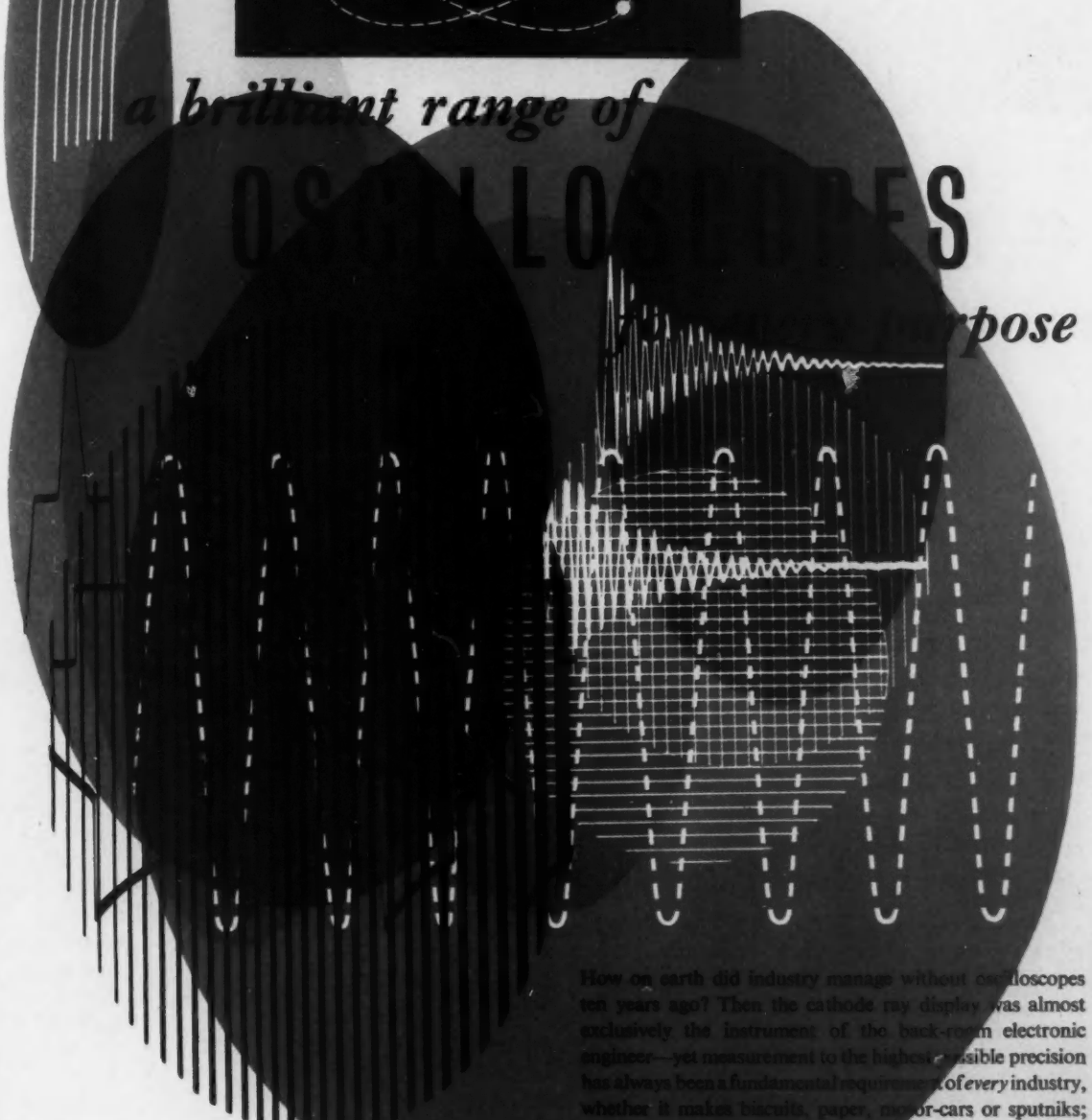
SAVAGE MASSICORE

SOLARTRON

a brilliant range of

OSCILLOSCOPES

...pose



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How on earth did industry manage without oscilloscopes ten years ago? Then the cathode ray display was almost exclusively the instrument of the back-room electronic engineer—yet measurement to the highest possible precision has always been a fundamental requirement of *every* industry, whether it makes biscuits, paper, motor-cars or sputniks; big, little; simple, complex.

The most significant development of the past decade has been this startling glimpse of the obvious—that the oscilloscope is now the standard measuring instrument of every industry, in the plant not just in the "back room", as automatically accepted as the micrometer, the weighing balance or the thermometer.

Overleaf we have presented ten outstanding oscilloscopes of the Solartron range in a form which we hope will be helpful in deciding the right model for your field of activity. But remember too, that expert advice is freely available from Solartron, who make more 'scopes than anyone in Europe.

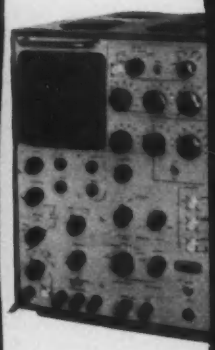
SOLARTRON COMPANIES OR AGENTS IN ALL PARTS OF THE WORLD.

HOW TO CHOOSE YOUR

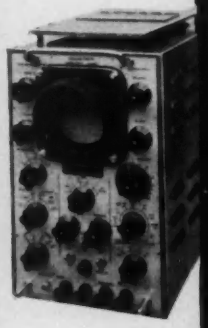
SOLARTRON

OSCILLOSCOPE

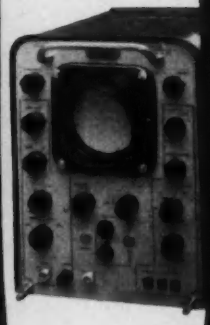
Please remember that skilled Solartron applications engineers are available at all times to advise on the best 'scope to use on your specific research or production task. Our Instrument Sales Division at Thames Ditton will record your enquiry for immediate action. Ring EMBerbrook 5522. (London).



The most accurate measuring oscilloscope in production today, the Solartron CD 643S measures time and amplitude to better than 2% over a bandwidth of DC to 12 Mc/s.



For field or Services' use the comprehensive user facilities and wide time-base range provided in the CD 523S.2 make this a particularly versatile general-purpose oscilloscope.



Lightweight and portable, the new CD 814.2 constant-bandwidth 'scope is equally suitable for technical training or servicing of TV and other complex electronic equipment.

FIELD & SERVICE USE

JOINT SERVICE APPROVAL

These three oscilloscopes have full Joint Service Approval. This is only granted after exhaustive testing of production oscilloscopes to Specification K 114F—a series of stringent vibration and environment tests especially framed by the Ministry of Supply to ensure peak reliability of Service equipment under all field conditions.

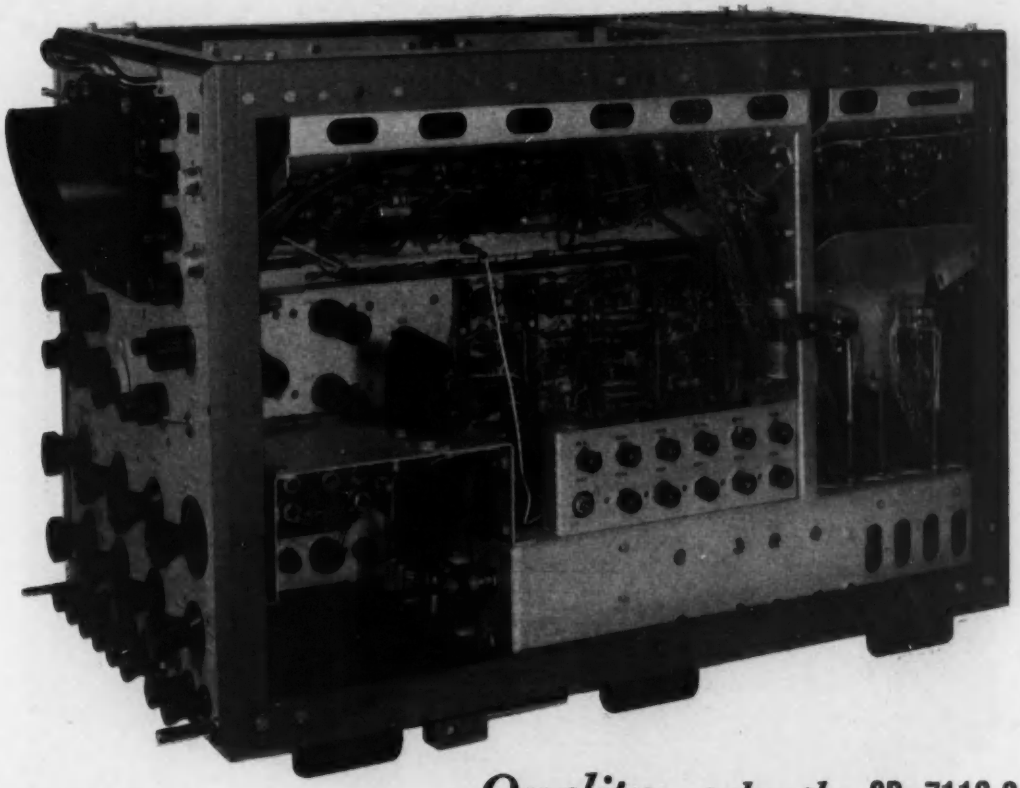
CD 711S.2	CD 643S	CD 523S.2	QD 910
			BANDWIDTH: DC to 1 Mc/s (Y_1 and Y_2).
			MAX. SENSITIVITY: 10 mV/centimetre. Constant bandwidth.
			TIME BASE RANGE: 1 μSec/cm—10 Sec/cm.
		TIME BASE RANGE: (Incl. expansion) 0.02 μSec/cm— 1 Sec/cm.	CALIBRATION ACCURACY: 5% velocity. 5% amplitude.
		CALIBRATION ACCURACY: 10% velocity. 10% amplitude.	T.B. TRIGGER DELAY: 10 μSec to 100 Sec.
		Socket for power probe.	Push-button or auto-erase time is 0.2 Sec. 'Z' modulation input. Triggering from ext., int., or push-button, or via delay generator.
	ADDITIONAL FACILITIES: 'Z' modulation input. Up to x 100 'X' expansion. Calibration is by precision triple-decade switching. Direct access to plates. 0.5 μSec. signal delay.		

PULSE WORK

EDUCATION

GENERAL PURPOSE

RADAR and Communications



Quality—take the CD 711S.2 *for example*

AD 557	CD 814.2	CD 518/CD 568	CD 513.2
BANDWIDTH: DC to 1 Mc/s.	**BANDWIDTH:** 0.9 c/s to 9 Mc/s to 12 Mc/s (6 db).	**BANDWIDTH:** DC to 5 Mc/s.	**BANDWIDTH:** DC to 10 Mc/s.
MAX. SENSITIVITY: 3 mV/centimetre.	**MAX. SENSITIVITY:** 40 mV/centimetre. Constant bandwidth.	**MAX. SENSITIVITY:** 0.4 V/centimetre.	**MAX. SENSITIVITY:** 1 mV/centimetre.
SENSITIVITY AT MAX. BANDWIDTH: 30 mV/cm—100 V/cm.	**TIME BASE RANGE:** (inc. expansion) 0.02 μSec/cm—0.01 Sec/cm.	**SENSITIVITY AT MAX. BANDWIDTH:** 10 V/centimetre.	**SENSITIVITY AT MAX. BANDWIDTH:** 10 V/centimetre.
TIME BASE RANGE: (inc. expansion) 0.1 μSec/cm—1 Sec/cm.	**CALIBRATION ACCURACY:** 5% velocity (marker pips). 5% amplitude. (50 c/s substitution).	**TIME BASE RANGE:** 0.1 μSec/cm—10 mSec/cm.	**TIME BASE RANGE:** (inc. expansion) 0.025 μSec/cm—0.1 Sec/cm.
CALIBRATION ACCURACY: 10% velocity. 5% amplitude.	Weight only 42 lbs. (20 kg.) 6-centimetre picture at 9 Mc/s. Integral TV sync. separator.	**CALIBRATION ACCURACY:** *CD 518:* 1 μSec and 10 μSec markers, Accuracy 2%. 1 μSec sinusoid, Accuracy 1%. *CD 568:* Sinewaves at 1, 10 and 100 μSec periods, Accuracy 1%. 2% Amplitude (by meter).	**CALIBRATION ACCURACY:** 5% velocity. 5% amplitude.
ADDITIONAL FACILITIES: Power output for ancillaries. Long-persistence tube with flare suppression. Direct access to plates.		0.6 μSec delay line. T.B. delay 0—10 mSec. Designed for field use.	Access to plates. TV sync. input. Socket for power probe.

Adopted for use by the British Armed Services and by NATO, the Double-Beam CD 711S.2 is a typical example of Solartron's adherence to precise manufacturing standards. With stability of performance assured by components which meet Spec. DEF 5000, backed by generous yet functional construction, the purchaser of a CD 711S.2—or indeed any Solartron oscilloscope—is assured of a fine investment.

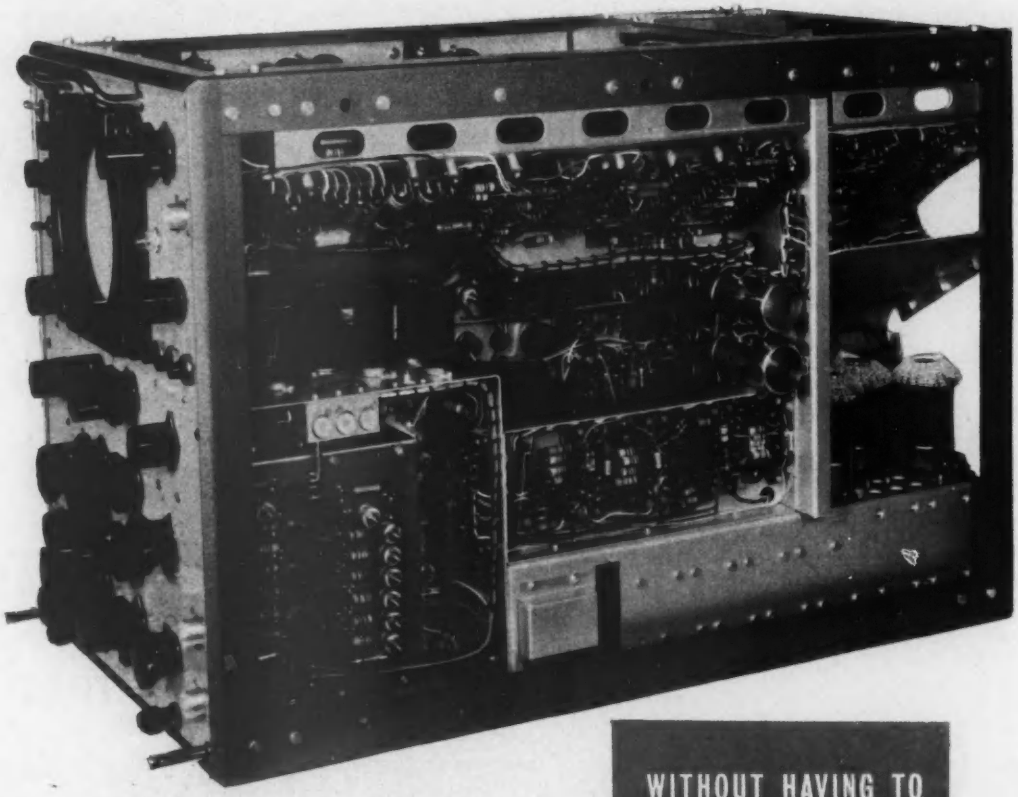
EDUCATION

GENERAL PURPOSE

RADAR and Communications

GENERAL PURPOSE

how to capture a transient...



WITHOUT HAVING TO TRY VERY HARD

This latest, important addition to the Solartron oscilloscope range represents a significant advance in detailed examination of "once-in-a-lifetime" phenomena. The IPO has already been ordered in quantity for use in United Kingdom Atomic Energy Establishments and is widely recognised as the leading tool for analysis of non-repetitive phenomena. The versatility of the instrument completely eliminates the need for time-wasting photography with all its attendant shortcomings. Using a 'Memotron' tube, the IPO has a writing speed of better than 125,000 cm/Sec., (8 μSec/cm) with an erase time of less than 0.2 Sec. Both 'Y_1' and 'Y_2' channels are DC coupled and have a max. sensitivity of 10 mV/cm, whilst for convenience of X-Y plotting 'X' and 'Y' amplifier sensitivity ranges are identical between 100 mV/cm and 30 V/cm. Time base switching provides seven basic decade ranges from 1 μSec/cm to 10 Sec/cm, each of which may be further sub-divided seven times between x1 and x10. Write for detailed literature.

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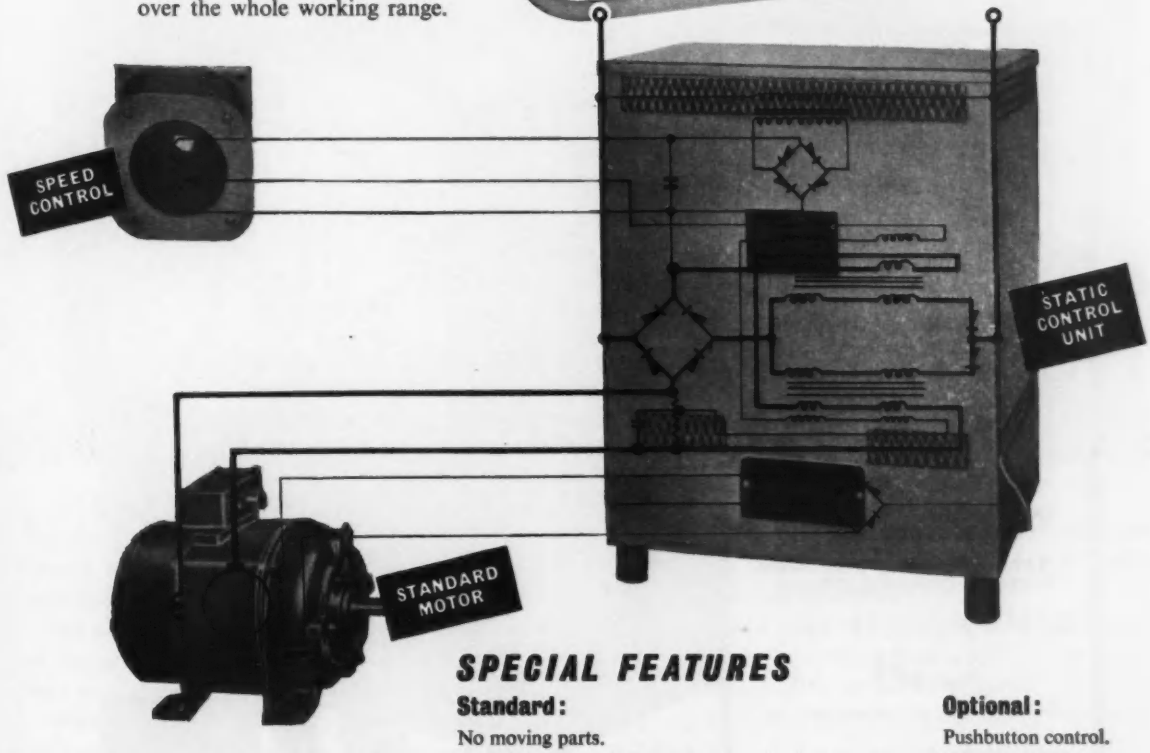

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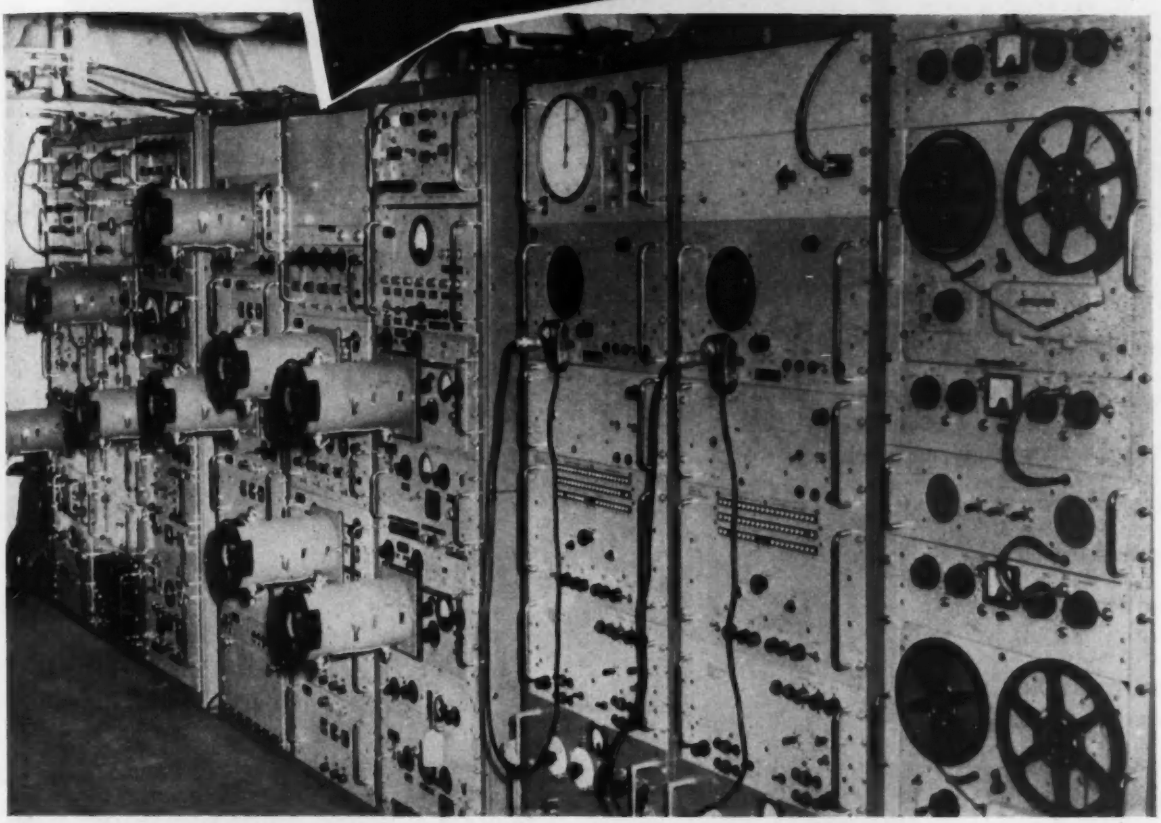

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ENERGY UNDER
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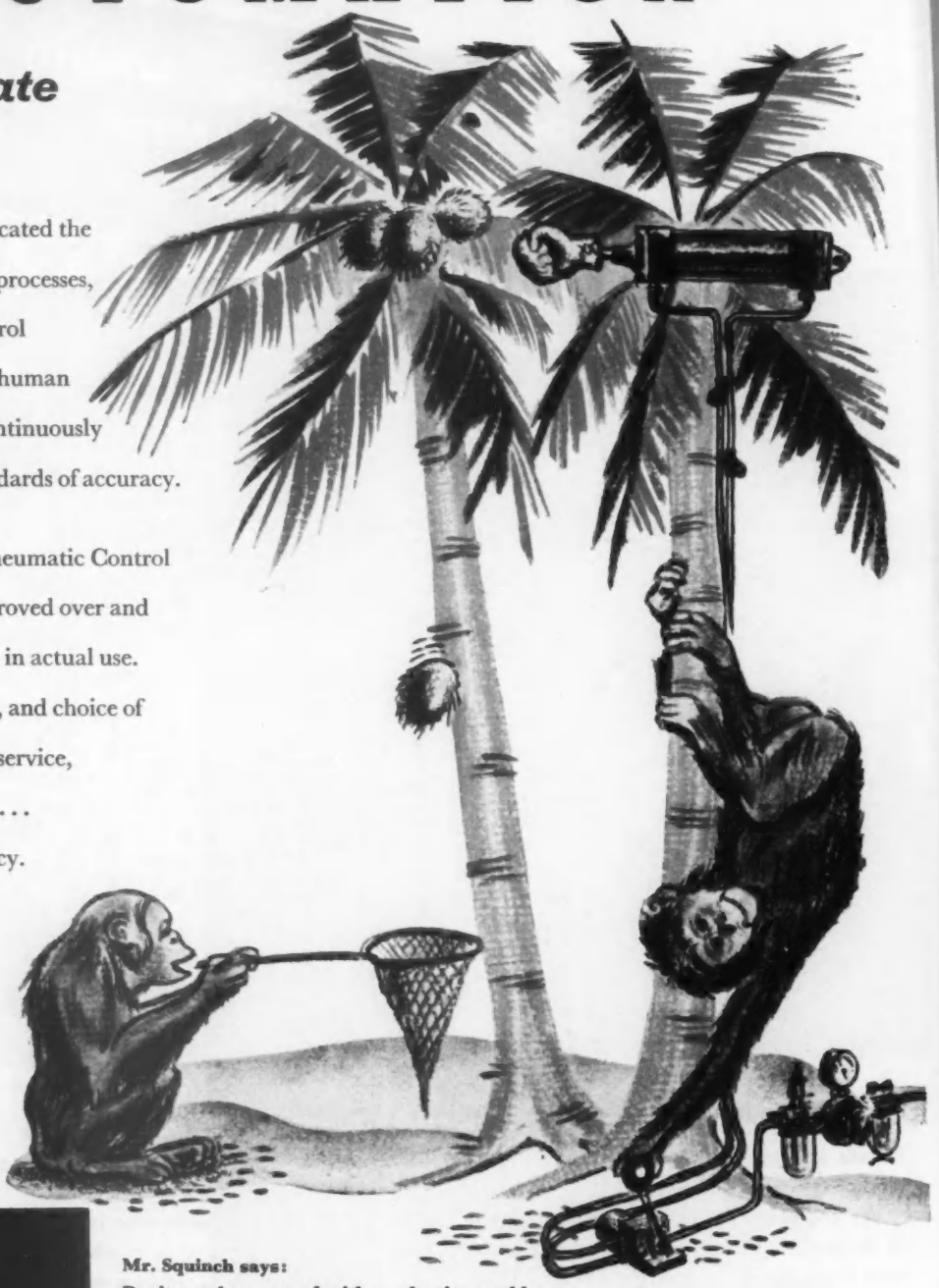

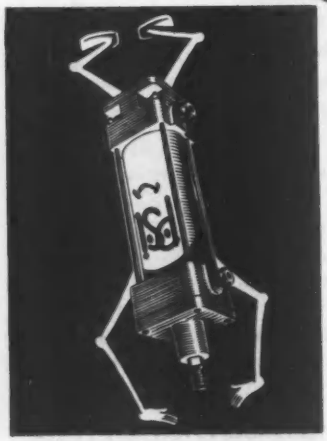

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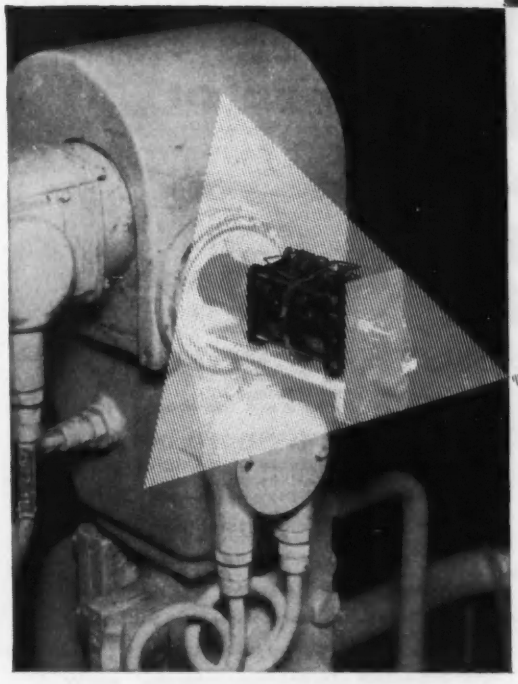
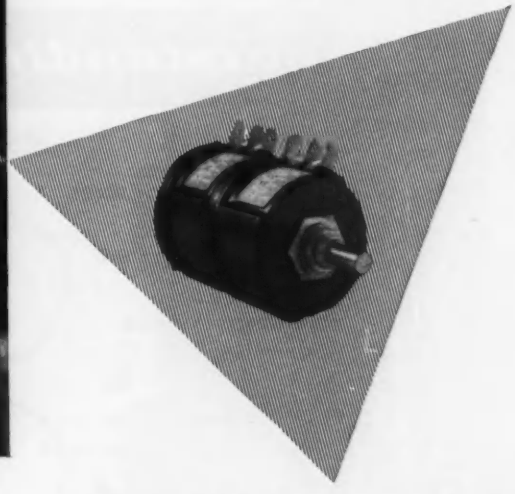


The Rolls-Royce Altitude Test Plant at Derby uses Beckman/Helipot Potentiometers exclusively for valve position control and generation of control signals.



Above: Series 'C' Helipot, two gang unit, mounted on a large control valve at the Rolls-Royce Altitude Test Plant, Derby. These potentiometers ensure an accurate and fine control of temperature and pressure in the engine test cells, corresponding to the desired altitude conditions.

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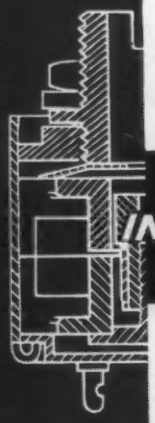

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EASY MAINTENANCE—The perfectly flat seats on both nozzle and disc can very easily be resurfaced when necessary without the necessity of critical control of seat widths and angles; in fact the tools can easily be taken to the valve; it does not have to be taken to the tools.

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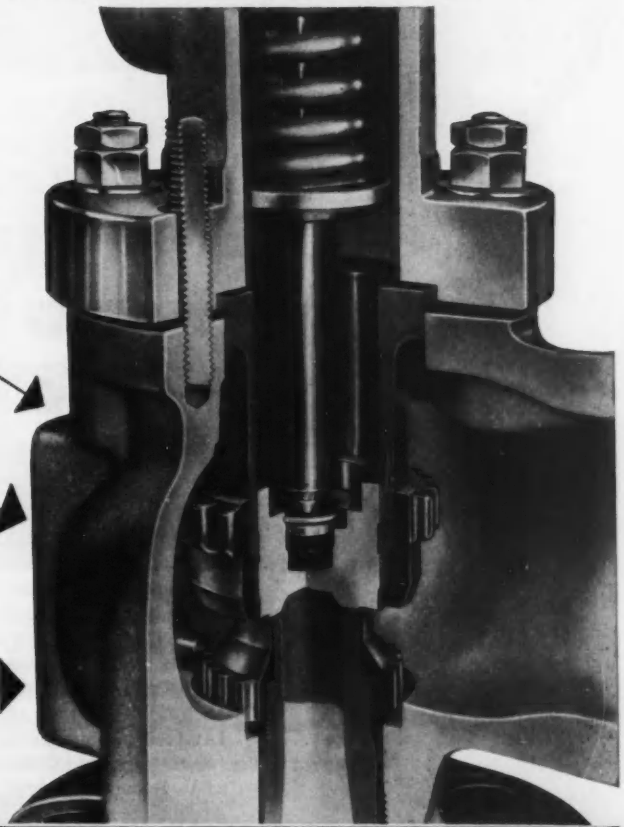

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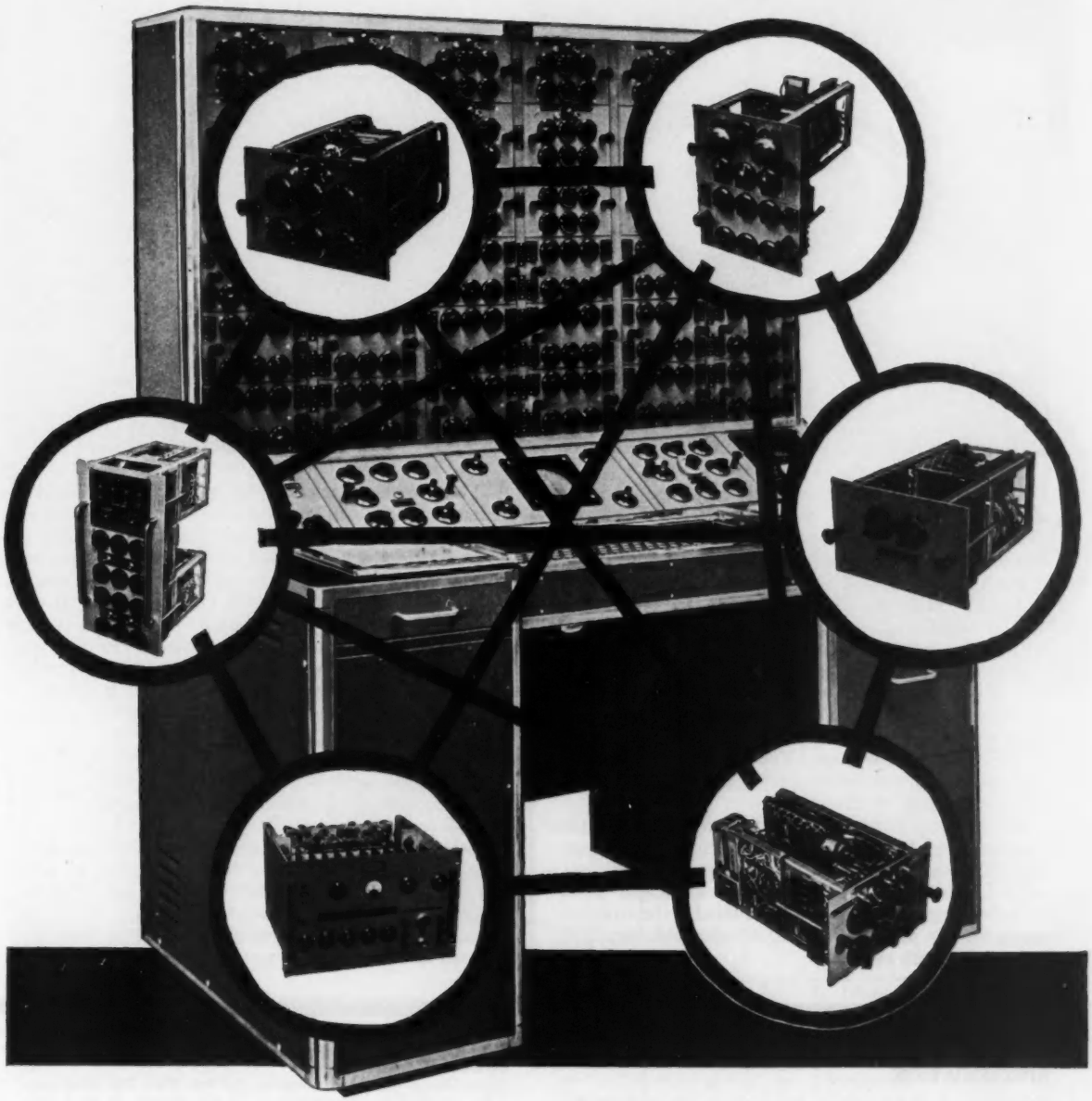

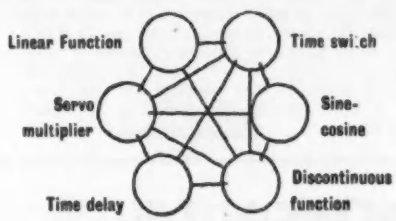

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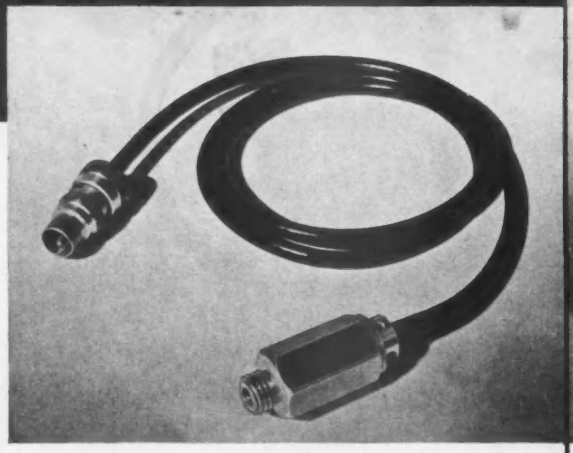


These are a miniature, fully screened type of accelerometer designed and manufactured by the General Electric Company of England and employing barium titanate ceramic elements.

Each unit consists of a thin disc of polarised ceramic, bonded between two pieces of metal. One piece forms the base of the accelerometer and is fitted with a stud by which the accelerometer is fixed to the apparatus under test. The other piece acts as an inertia weight which imposes strains on the disc when the unit is subjected to acceleration. These strains induce on the disc, electric charges which can be detected as a measure of the applied acceleration. The accelerometer is fitted with a length of low-noise screened cable for connection to the measuring circuit.

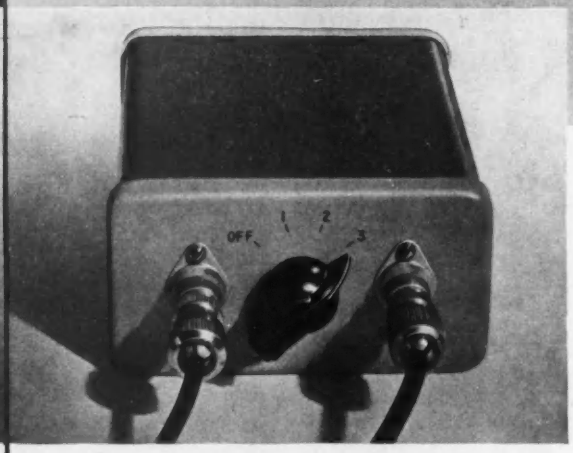
For optimum results, especially at low frequencies, the accelerometer should be connected to a high input-impedance amplifier such as our pre-amplifier type M1201. Either graphited or silicone-lubricated cable, 32 inches long, is normally supplied fitted to the accelerometer for this purpose. An individual calibration sheet is furnished with each unit.

DATA. (Average Values).

SPECIFICATION

Sensitivity: 4 pica-coulombs per g (g is the gravitational constant of acceleration) parallel to axis. *Capacitance:* 170 pF. (without cable). *Output:* 15 mV/g with 32 inches cable. *Frequency Response:* Flat ± 10%, 40 to 10,000 c/s. *Temperature Range:* —50 to + 100 deg. C. *Max. Acceleration:* 1000g. *Transverse Response:* Not greater than 5% up to 5000 c/s. *Weight:* 18 grammes. *Dimensions:* 1¼ ins. long from mounting face. $\frac{11}{16}$ ins. across corners of hexagon. $\frac{3}{8}$" BSF fixing stud, ¼ in. long.

M1201
PIEZO PRE-AMPLIFIER



This pre-amplifier has a high input impedance and is suitable for use with piezo type transducers. The circuit employs one miniature valve and four transistors and is operated from self-contained replaceable dry batteries. The front panel carries input and output sockets and a four-position switch, labelled OFF, 1, 2, 3. In the numbered positions, the amplifier is switched on and in position 1, the maximum gain is realised. In positions 2 and 3, capacitors are switched in parallel with the input to form capacitative attenuators with the self-capacitance of the transducer and its associated cable.

The circuit comprises a three-stage transistor amplifier preceded by a normal cathode follower valve. Overall feedback is taken through the fourth transistor to make the D.C. gain small and ensure a high degree of temperature stabilisation of the D.C. operating conditions. The rugged construction of the pre-amplifier ensures the minimum response to vibration. The wiring is in the form of a printed board and the cathode-follower circuit is fully encapsulated.

DATA.

SPECIFICATION

Input Characteristics: Resistance not less than 100 megohms, 2 c/s. to 20 Kc/s. Capacitance, 20 pF. approx. in max. gain condition (Position 1). *Output:* 1 volt r.m.s. max. Load capacitance 1000 pF. max. Load resistance 100 K ohms min. *Gain:* × 40 approx. *Frequency Response:* 5 c/s. to 15 Kc/s., 10% down. 2 c/s. to 30 Kc/s., 30% down. *Attenuator shunt capacitance:* Position 2: 1000 pF. Position 3: 4000 pF. *Batteries:* Mallory SKB768 (10 off). *Battery life:* 200 hours approx. *Size:* 3⅜ × 2¼ × 4½ ins. (9·8 × 5·7 × 11·4 cm.). *Weight:* 1 lb. (0·45 Kg.).

SOUTHERN INSTRUMENTS

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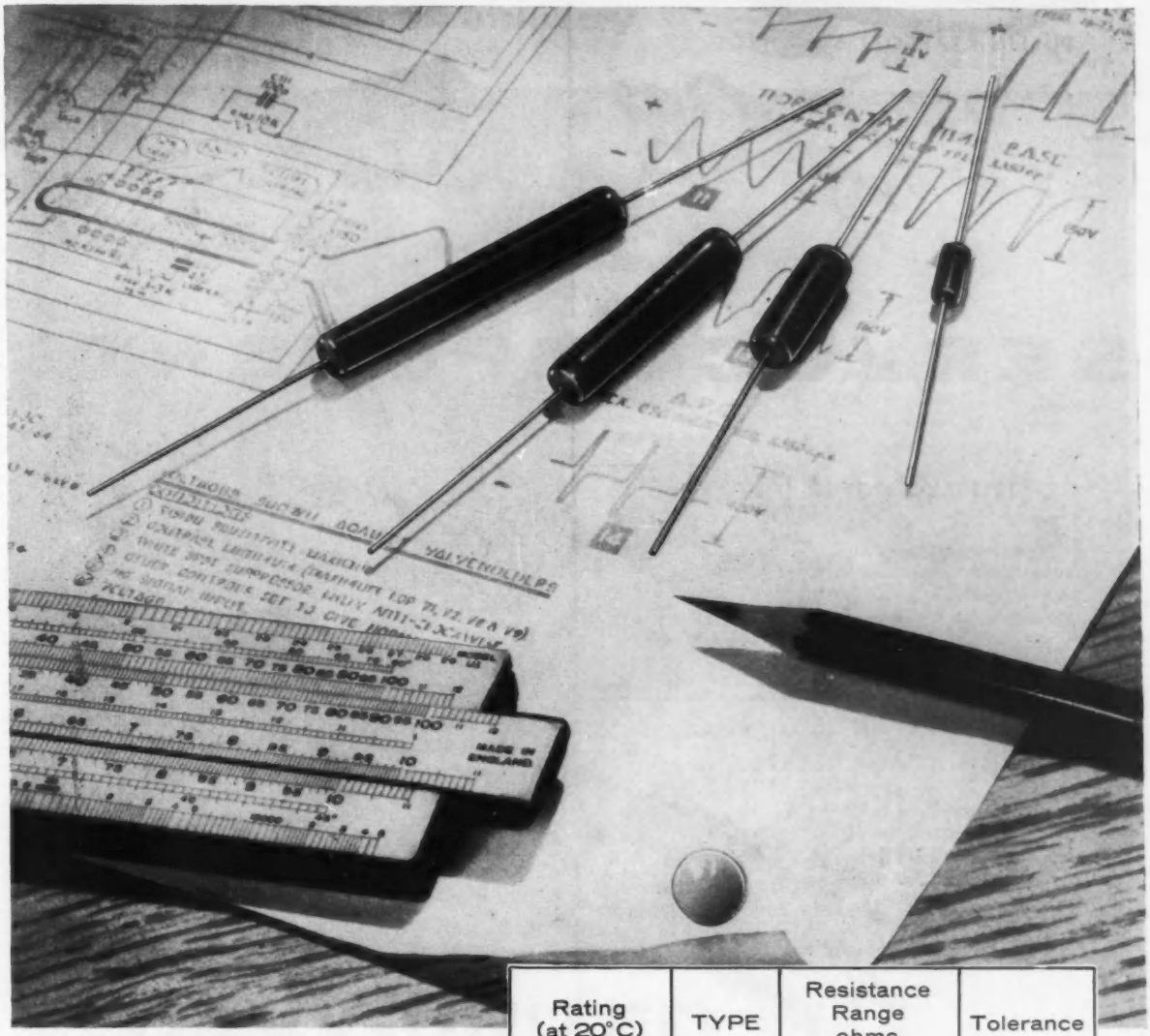

Rating (at 20°C) Watts	TYPE	Resistance Range ohms		Tolerance
		Min	Max	
4	MV1A	1 10	9·9 6,800	10% 5%
7	301A	2	68,000	5%
10	302A	4	140,000	5%
5	306A	1	33,000	5%

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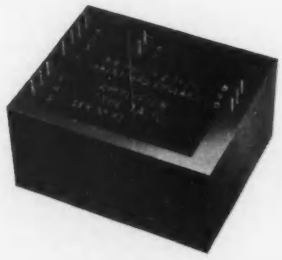
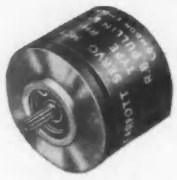


SERVOCOMPONENTS

SIZE 10 SERVO MOTOR

High performance, two-phase induction-type servo motor for thermionic valve or germanium/silicon transistor operation.



for precision in measurement and control

In many fields of application, precision in measurement and control is essential. The range of Pullin and Pullin-Kearfott servocomponents—a selection of which is shown here—are designed and engineered to perform that vital service. Remember "Pullin for precision", and write or telephone us for further information.

Systems Engineering. A Control Systems Division has been set up especially to provide design, manufacturing and technical advisory assistance to engineers engaged in servo work. If you have a problem regarding servo-components, mechanisms and integrated systems, our experts will gladly advise.

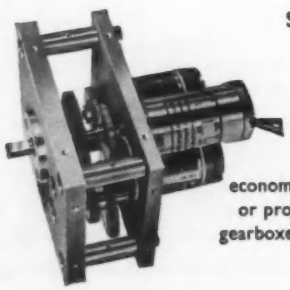
SIZE 10 MOTOR GENERATOR

Motor Generator Type R. 807 for 26 volt operation or with 20 volt centre-tapped control winding for germanium/silicon transistor working.

MAGNETIC AMPLIFIER

Hermetically sealed high power gain amplifiers for Sizes 15 and 18 servo motors and motor generators.

SERVO GEARBOXES



A unique gearbox service designed to provide at economical prices and in prototype or production quantities precision gearboxes for use in a wide range of servo applications

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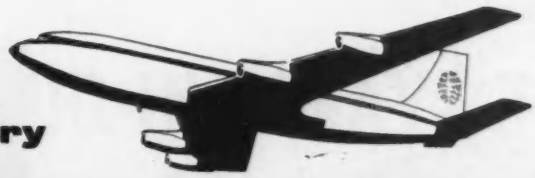
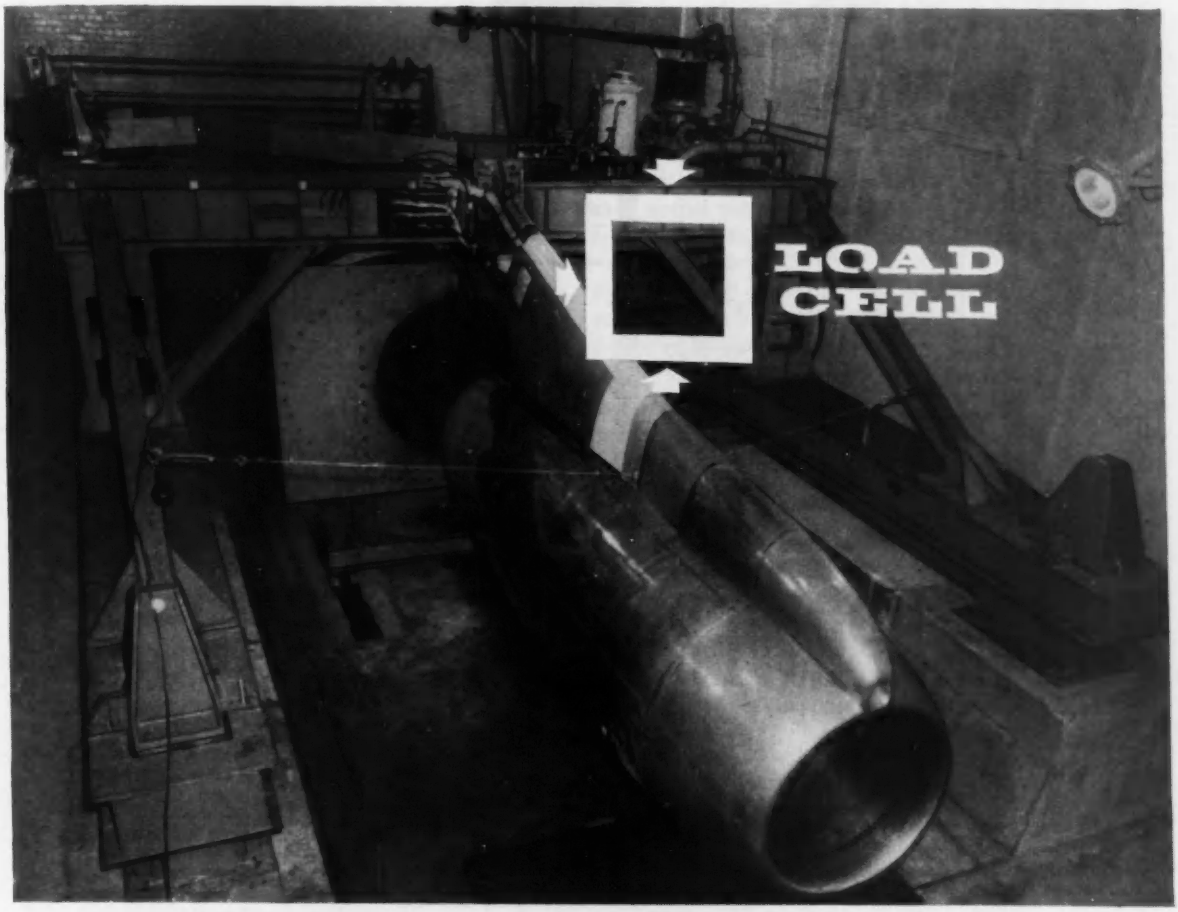
for the Aircraft Industry





DAVY-UNITED LOADCELLS

FOR TESTING ROLLS-ROYCE CONWAY ENGINES

This special test bed installed by Rolls-Royce Limited at their Hucknall Flight Test Establishment for the testing of Conway by-pass engines, utilises Davy-United Precision Mk. 7 Loadcells and "Highspeed" indication system for the measurement of both forward and reverse thrust. The equipment has a speed of response of less than 1 second for full scale deflection on a 36" indicator, while an automatic scale expansion device allows engine thrust to be measured from 10,000 reverse to 20,000 lbs. forward with an accuracy of ±10 lbs. throughout an entire test programme lasting several days.

DAVY-UNITED

B19/DU/1

DAVY AND UNITED INSTRUMENTS LIMITED, DARNALL WORKS, SHEFFIELD 9

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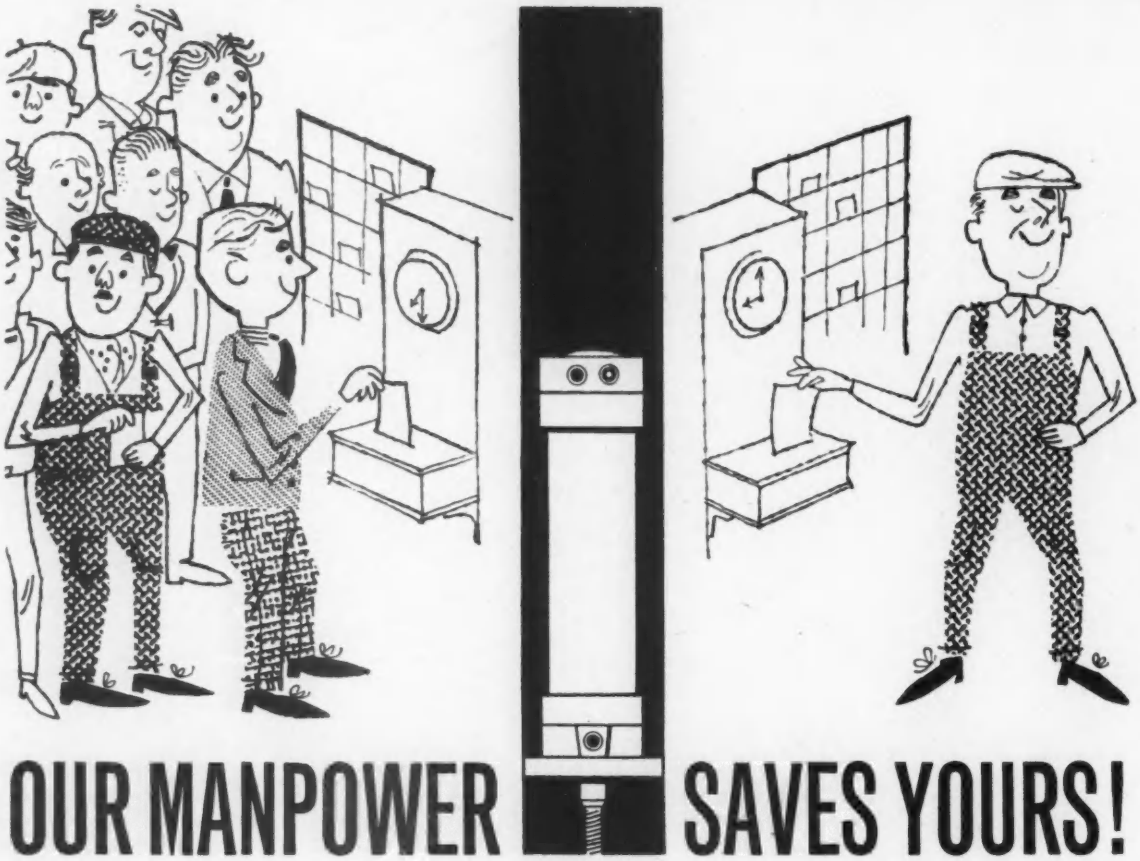

OUR MANPOWER SAVES YOURS!

In almost every industrial process there is some stage where manpower could be cut by the application of fluid power. It is here that our labour can prove so labour-saving, since the whole weight of the Baldwin Fluid Power Division is directed at cutting waste manpower and speeding production.

BALDWIN TECHNICAL REPRESENTATIVES
cover the British Isles. They are experienced fluid power engineers, who will quickly show you how to harness waste or under-used power by fitting Baldwin equipment which, because of its unit construction, can be supplied from stock quickly.

Write now for the Fluid Power Catalogue C/503

THE EXPERT BALDWIN DESIGN STAFF
at Dartford will plan automation schemes for any operation or series of operations up to the largest automatic production lines.

HIGHLY SKILLED MEN
on the Baldwin shop floor devote their attention to producing the superb finish, reliability and precision that characterises Baldwin Fluid Power equipment. There is a standard range of 384 pneumatic and hydraulic cylinders and over 700 control valves.

We have long found that the best way to success is to give the best service. At every level, our manpower is aimed at increasing production for industry —and for Baldwin too, of course!

Fluid Power Division

Baldwin Industrial Controls

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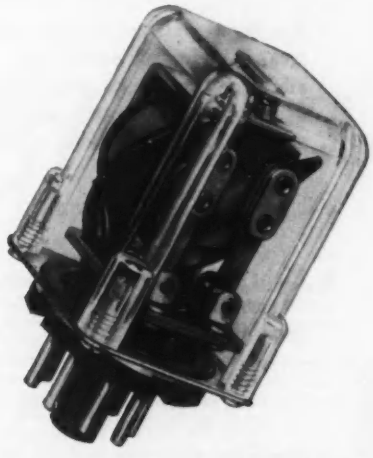
B/35

New...THORN PLUG-IN RELAYS

Thorn Pygmy Power Relay



New interchangable relay designed for use in remotely controlled automation units. Has double pole changeover contacts.

Dust proof—transparent plastic cover.

Plugs into any standard International octal valve base.

Weight Only 4½ ozs . . . projection only 2" above base.

Mechanical life over 10,000,000 operations.

Switching current: 5 amps maximum at 250 volts A.C.

Maximum surge current: 10 amps.

Operate time: 8 milliseconds approx.

Release time: 6 milliseconds approx.

Overall dimensions: 1⅜" square by 2$\frac{29}{32}$"

Coil voltage: 240 volts standard; also available for 6, 12, 24, 48, 60, 110 volts

Thorn T9 Micro-Switch Relay

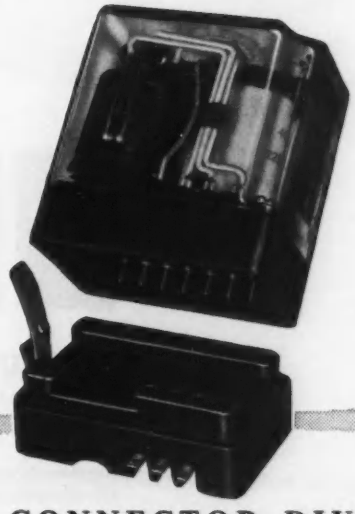
A plug-in relay, particulary suitable for switching P.A. equipment, the snap action contacts minimising interference with pick-up leads.

Operating coil wound for any specified voltage up to 240 volts A.C. or 150 volts D.C. May be tropicalised.

Up to three micro-switch pattern contacts mounted on standard coil frame.

Versions available with up to 11 solder tags or 10 screw terminals.

Contacts:	3 changeover.
Mechanical Life:	Over 10,000,000 operations.
C/O Time:	C.O. period less than 2 milliseconds.
Max. Switch:	10 amps/240 volts A.C. non inductive load.
Capacity:	0.2 amps/240 volts D.C. „ „ „ 0.5 amps/110 volts D.C. „ „ „ 1.0 amps/50 volts D.C. „ „ „ 5 amps/24 volts D.C. „ „ „
Max. Operate Speed:	20 cycles/sec.
Switching:	Up to 0.1 amp. approx. 20 cycles/sec.
Frequency:	„ „ 1 „ „ 5 „ „ „ „ 5 „ „ 1 „ „ „ „ 10 „ „ 0.1 „ „ (referred to A.C. non-inductive load).



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Thorn Electrical Industries Limited, Great Cambridge Road, Enfield, Middlesex. Telephone: ENField 5353

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24 Channel High Speed Recorder

For the analysis of stresses and strains, electrical waveforms, vibrations, pressures, displacements, heat transfers and other physical and physiological phenomena

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Direct writing ultra-violet recorders
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New Electronic Products Ltd

MAKERS OF SCIENTIFIC, MEDICAL AND INDUSTRIAL INSTRUMENTS

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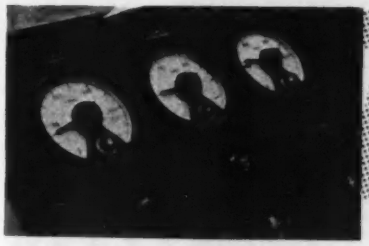


Fielden Controllers mounted on the sloping panel of a Brown Davidson Moulding Machine

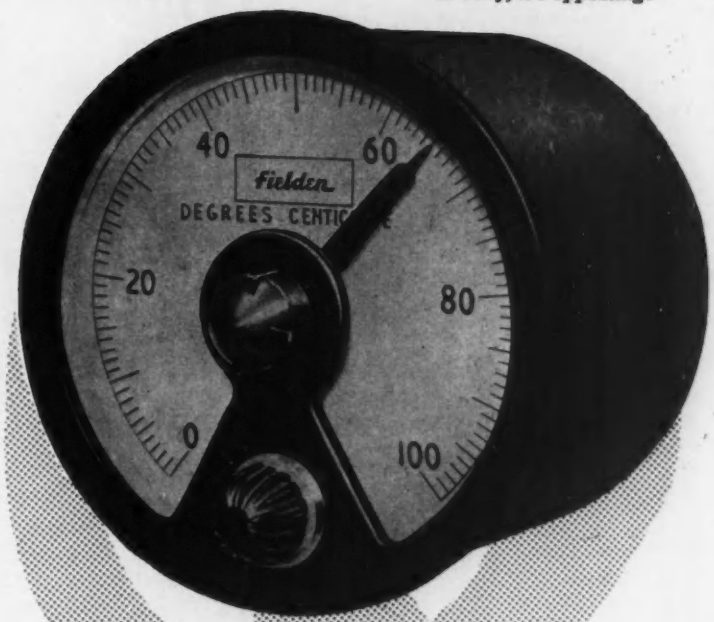
NEW BIKINI

TRANSISTORISED TEMPERATURE CONTROL to within 0.5° C

The first of Fielden's new BIKINI range of transistorised instruments. Result of three years intensive research, development and evaluation. Small in size and small in price, yet all essentials more than covered. In brief, it's appealing.

Low Cost—Send for details, you'll be surprised.
Transistorised—Exceptional reliability. No warming up period. 12V Battery or mains supply.
Intrinsic Safety—Low voltage, low current operation—Intrinsic safety certificate pending.
Very Robust—completely sealed unit requires no attention. No pivots, galvos or other delicate moving parts.
Easily fitted—simple clamp mounting with robust terminals for electrical connections. Can be mounted at any angle, for example on a sloping control panel.
Remote control—Instrument can be up to 300 ft away from the measuring point using simple copper wiring. Measuring element is of platinum resistance type, housed in a robust ¼" diameter stainless steel sheath.
Heavy Duty Contacts—Change over electrical contacts rated at 5 amps A. C. with quick make and break action. Pneumatic control available if required.
Accurate calibration—Accurately calibrated scale 9" long marked in °C or °F. Easily set to required control temperature.
High stability—Control point will not vary over many years service. Unaffected by ambient temperature changes or by wide variations in supply voltage.
Wide Temperature range—will control at any temperature between —200° C and +500° C with a differential of 0.5° C. Range spans as low as 50° C.
Modern and Compact—Circular meter type case. Occupies panel space of only 4½" diameter. Bold pointer shows control temperature. Red lamp, visible from sides and front, indicates control action.
Immediate delivery—Instruments ranged 0-120° C, 0-200° C, 0-300° C and 0-500° C available from stock in Manchester, London, Walsall, Stockton and Edinburgh. Other standard ranges in stock at Manchester. Telephone your urgent requirements to Wythenshaw 3251 Trafalgar 3154, Arbortum (Walsall) 55343, Stockton 68617 or Edinburgh 32035 (A. R. Bolton).

Write now for full specification sheet BIK. 1C with price list.



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Indicating Recording Control

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protects flame-traps

from the dangers of blow-back flames

ETHER FLAME-TRAP ANCILLARY UNIT

Patent applied for

TYPE 350

This new safeguard, the ETHER Flame-Trap Ancillary Unit, Type 350, will be invaluable in industries where pre-aerated gas or pre-mixed gases are used. At present, a flame-trap is normally provided to arrest the flame temporarily when a blow-back occurs, but unless it is noticed, the flame will ultimately burn through the flame-trap.

Now this hazard need no longer exist. The ETHER Type 350 introduces a detector in front of the element of the flame-trap by means of which the supply of gas is shut off, or an alarm given, within a fraction of a second of a blow-back occurring.

The Type 350 is foolproof, compact and low in price. It can readily be adapted to fit all existing flame-traps.
Illustrated technical data forwarded on request.

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PRESS-TO-TEST
WARNING LAMP
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- ***Instant filament checking***
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- ***Sealed against dirt and moisture***

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PAGE 3

FIRE DESTROYS LOCAL FACTORY

Electrical fault causes disastrous blaze

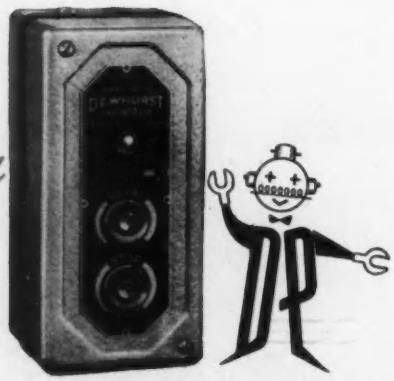
This afternoon, fire broke out in the new factory belonging to a leading local manufacturer. It is understood that, during the lunch time break, an electrical motor burnt out which ca

...and it could happen to you!

In every factory where there are electric motors, there is the ever present danger of fire due to electrical faults such as single phasing and overloading — especially when starters are used that do not include the protection that is a basic part of the DUPAR TFK Starter.

Don't be tempted to economise on a starter that may be a few shillings cheaper, but does not include this positive protection.

THE DUPAR TFK STARTER INCLUDES THE SPECIAL ET PROTECTOR
— your insurance for complete safety of motor operation



DUPAR *for dependability*

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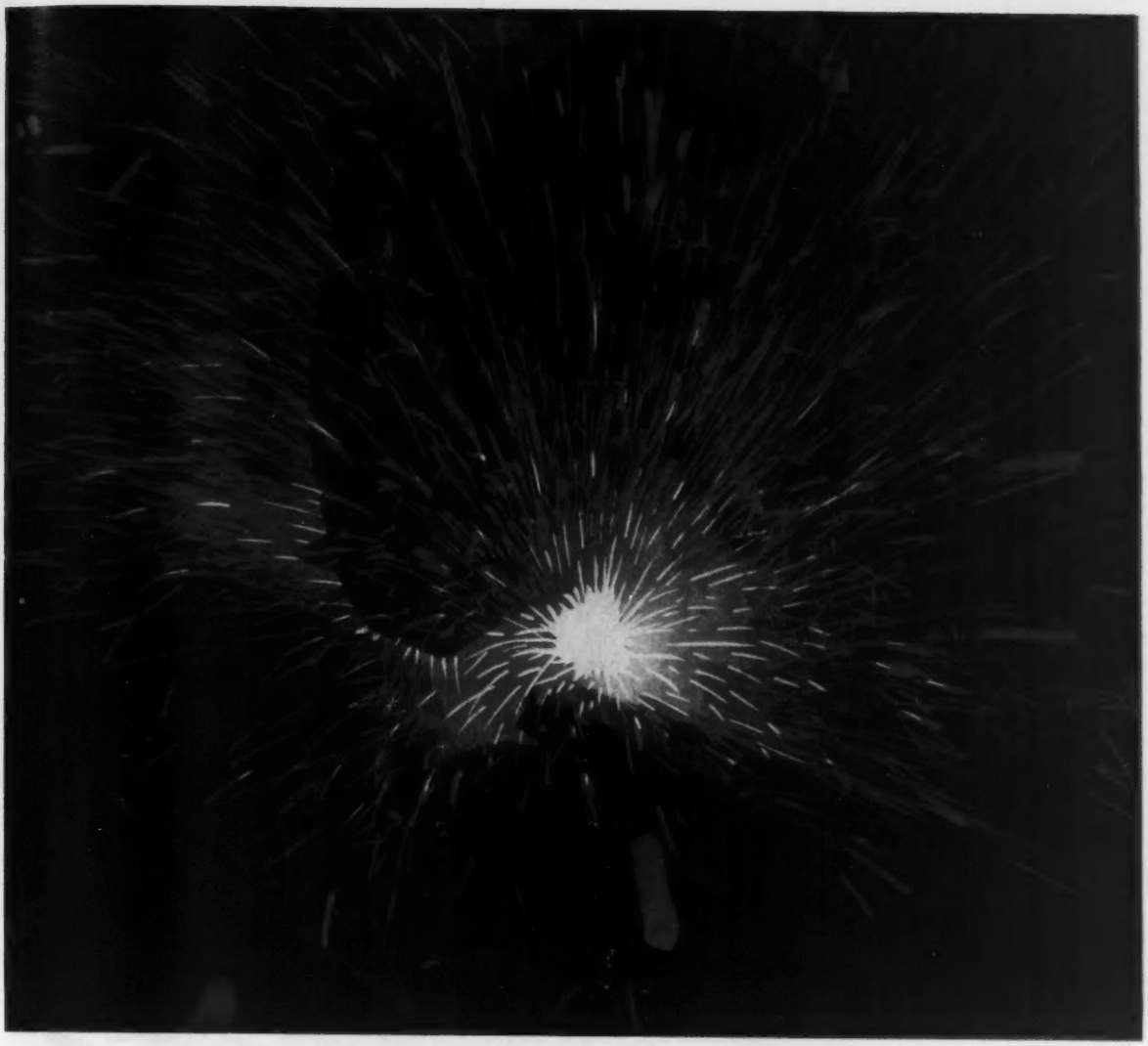

Steel

For many years the precise control associated with 'VSG' variable delivery hydraulic pumps and transmission gears has proved invaluable to the Steel Industry.

Mill and drawbench drives, sawing and measuring tables, processing machines and manipulators are a few examples of the many applications of 'VSG' equipment.

The Steel Industry is but one of many industries which 'VSG' has now been serving for over fifty years.

'VSG'

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CERTAINLY DO ITS JOB WELL . . ."

* *GUINNESS*
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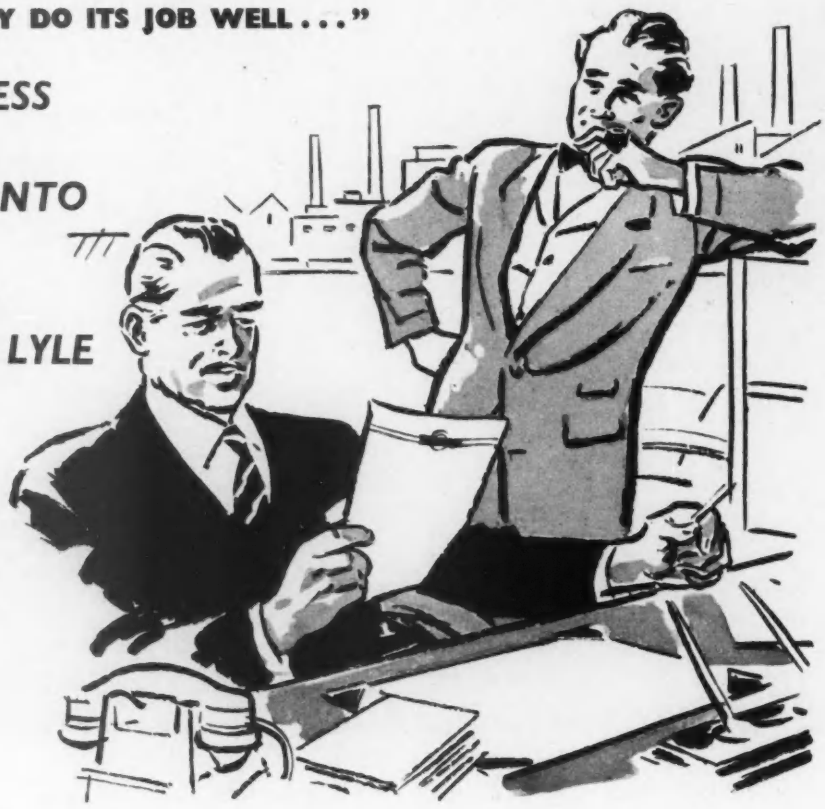

. . . and these are just a few of the many well-known

Companies who use Radiovisor Smoke Density Indicators and Recorders

for efficient combustion and to comply with the Clean Air Act.

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STANHOPE WORKS, HIGH PATH, LONDON, S.W.19
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raised to rolling temperatures under the control of Honeywell instruments at the new Brinsworth mill of Steel Peech and Tozer Ltd. The system ensures desired temperature distribution, with maximum fuel economy.

8,700 gallons of petroleum an hour
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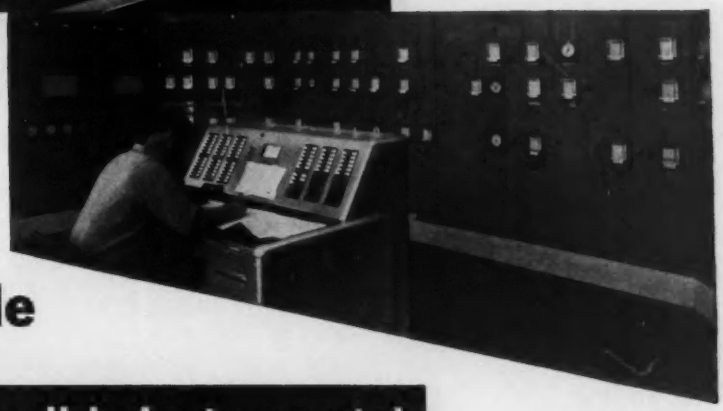

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In steel . . . petroleum . . . and every major industry, automatic controls by Honeywell are now *built in* to new large-scale processing plant. Comprehensive systems—composed of miniature or conventional instruments—are engineered and supplied as completely piped and wired panels ready for installation.
When in action, each control system—designed and built *for the plant* from interlocking standard Honeywell units—maintains a complex of process conditions at a stable optimum as accurately as a single instrument for one variable.

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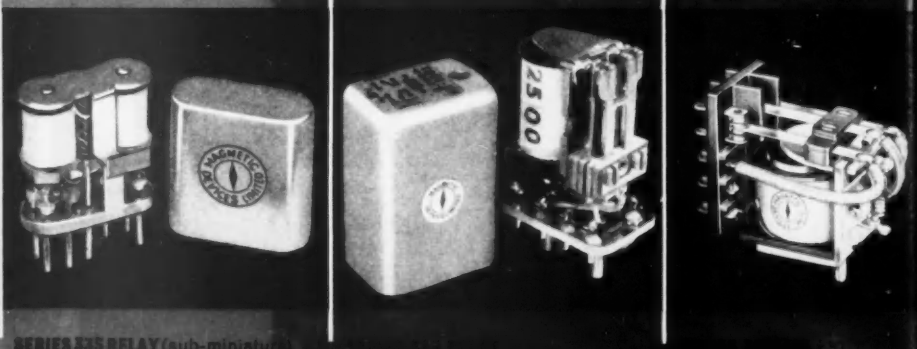
Sales Offices in principal cities throughout the world.

Honeywell
First in Control

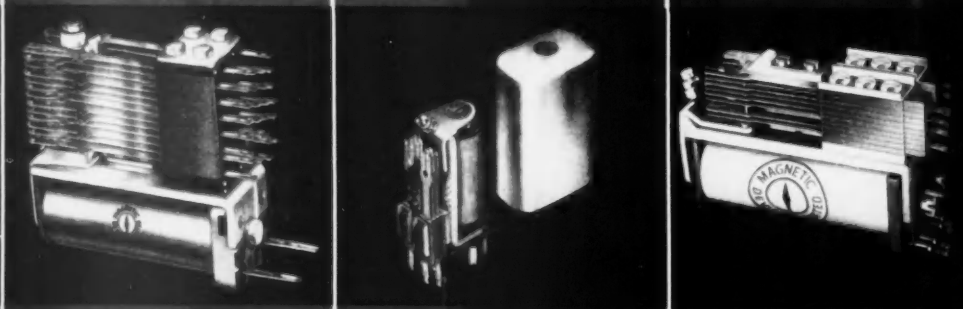
Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
335	5,400	85	1.2 watts (max.)	2 amps.
315	2,500	48	1.25 watts	10 amps.
320 325	9,200	440 250	5 VA 2.5 watts	10 amps. at 30v. D.C.



specifications

SERIES 335 RELAY (sub-miniature) Balanced armature 2C contacts, hermetically sealed. Mounting and socket bases to customers' requirements. Dims.: 0.8" x 0.35" x 1". Wt. ½ oz. Minimum contact pressure 8 grams.

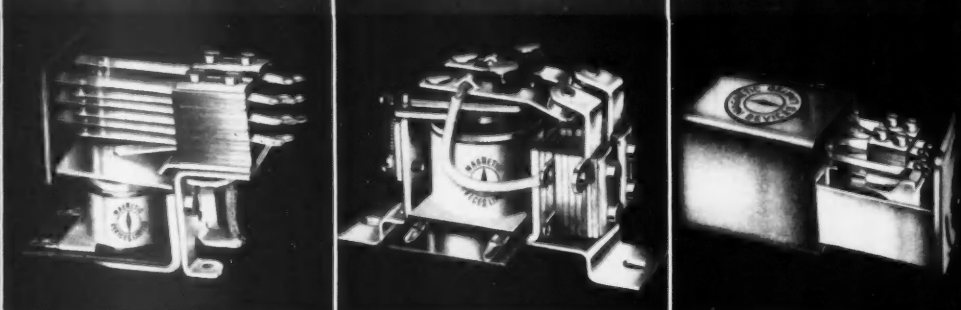
lay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
85	12,500	250	3.6 watts (max.)	6 amps.
00	14,000	240	0.16–4 watts	5 amps.
05	40,000	250	80 milliwatts to 6 watts	8 amps.



SERIES 285 RELAY For industrial, electronic and automation applications. Up to 10 C.O. light duty contacts or 8 C.O. heavy duty. Dims.: 2.37" x 0.91" — 3.12". Coil up to [illegible] D.C.

SERIES 3400 Sensitive enclosed [illegible] electronic circuits. Mounting dimensions identical with B.P.O. 600 relay 6 N.O. or 5 C.O. contacts. Dims.: 1⅞" x 2⅛" x 2⅜" max. Coil up to 250v. D.C.

lay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
0 5	6,000 10,800	440 250	3–6 VA. 1.5–3 watts	10 amps.
1 6	7,500 9,800	440 250	5–6.6 VA. 2.6–3.3 watts	15 amps.
8	1,400	24	Independent of controlling supply	5 amps.



SERIES [illegible] RELAY Sil[illegible] 6M or 4B or 4[illegible] insulation up to [illegible]v. D.C. Dims.: 2¼" x 1⅛" x 2⅛" max. Max. coil up to 300v. A.C. 180v. D.C.

SERIES 151/156 RELAY Small relay for heavy duties. 2M or 3B or 2C plus one light [illegible] if required. Dims.: [illegible] x 2¾". Coil up to [illegible] D.C.

SERIES 806 [illegible] torised). Hermetically [illegible] relay for control by ultra[illegible] contacts. Will handle [illegible] loads, e.g. contactors, solenoid[illegible] heaters etc., but is control[illegible] by extremely light curre[illegible] Type A controls volts 2, [illegible] & relay Type C, control volt[illegible] [illegible] approximate

prototypes

PRIORITY is given to all prototype samples to enable engineers to proceed with their designs with th[illegible] minimum of delay.

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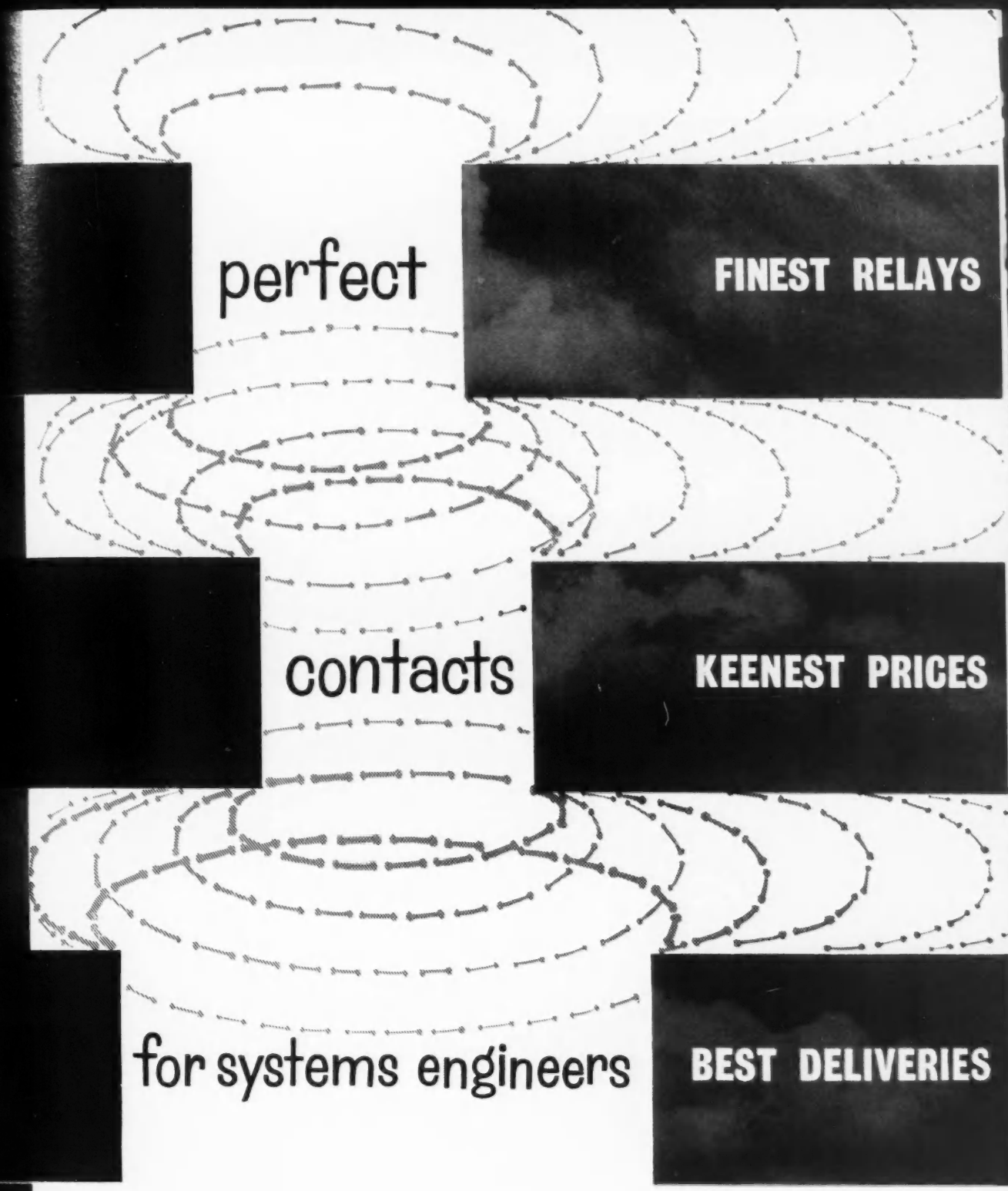

When designing control systems for completely reliable operation experienced engineers have absolute confidence in approaching **Magnetic Devices Limited** for Relays.

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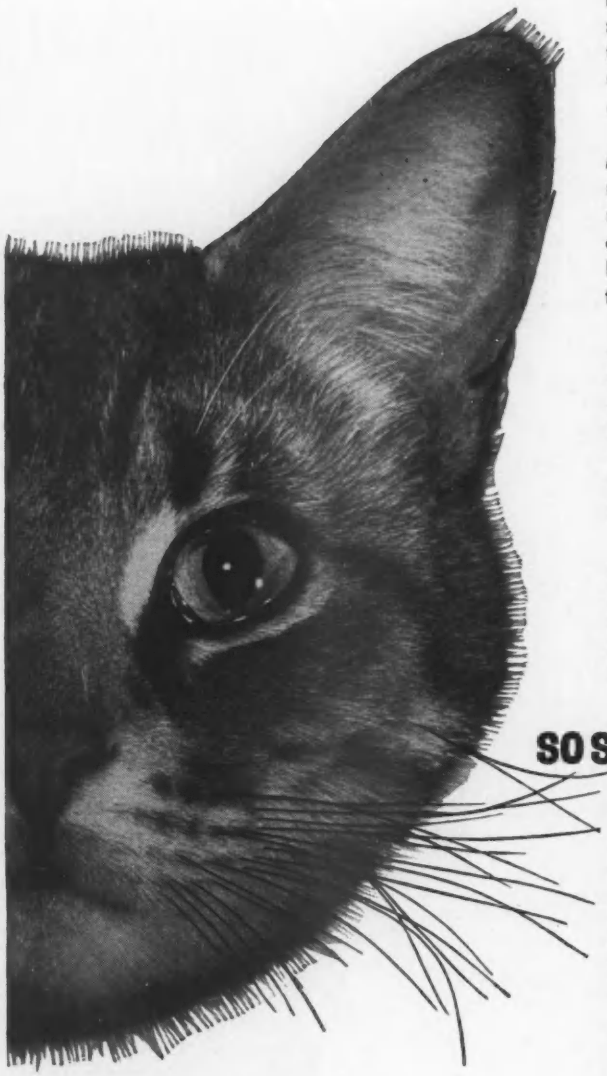

MANY TIMES MORE SENSITIVE than any similar apparatus on the market! This is the outstanding feature of the ERICSSON ANALOGUE/DIGITAL CONVERTERS which form the basis of a new and exciting range of precision instruments.

This sensitivity (*minimum detectable increment 10 micro volts*) means that these instruments which utilize transistors and relays throughout can be used without pre-amplification to measure the output from thermo-couples, strain gauges and load cell bridges etc.—a unique application in the field of digital recording.

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If you are concerned with the collection, presentation and logging of data and/or in complete systems, consider the advantages offered by this new range of instruments in the form of high sensitivity, advanced circuit design, modular construction and versatility of output.

SO SENSITIVE

TYPE NO.	APPLICATION
Industrial Analogue-Digital Converter Type 154A	Normally part of an installation. To be used where remote indication is required, or for printing and punched card systems.
Industrial Analogue-Digital Converter Type 306A	Particularly for isolated measurements. As Type 154A but with integral digital indication.
Digital Strain Meter Type 170A	For use with load cells and other types of bridge network. To be part of an installation. For print out and punched card applications.
Digital Strain Meter Type 307A	As Type 170A but for use where digital indication only is required.
Digital Ohmmeter Type 156A	Laboratory or factory test instrument to read resistance or resistance tolerance.

**The word 'DIGITRON' is an Ericsson Registered Trade Mark*

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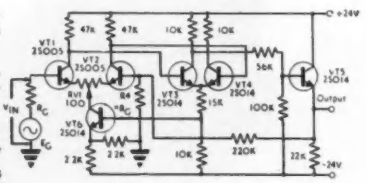

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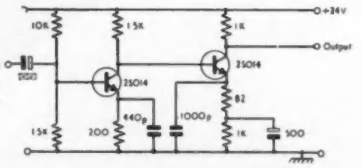

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JANUARY 1960 VOL 3 NO 19

CONTROL

Space for Improvement

'WHAT shortage? This is often the retort of an engineer these days if he is told of a lack of trained technologists. Yet last month's report of the Advisory Council on Scientific Policy told him just that*. Certainly the *Sits. Vac.* columns are full, and certainly most of the *Sits.* are technical and scientific. This may seem to support the latest official statistics: but while the area of magazine or newspaper covered by the advertisements is large, the area per advertisement is also great, and the frequency of vacancies is smaller than it may appear. In fact, from the works-eye view, there probably seem to be more well-qualified engineers seeking posts than sought after. Are then the statistics wrong or misleading, and has the Advisory Council indeed been misled? In pondering these questions, let us consider a little history.

Once upon a time it was thought that the safety of this kingdom depended on the size and potency of its military aircraft, so an industry was born and nurtured and brought to prosperity. To-day the industry is too big for its markets.

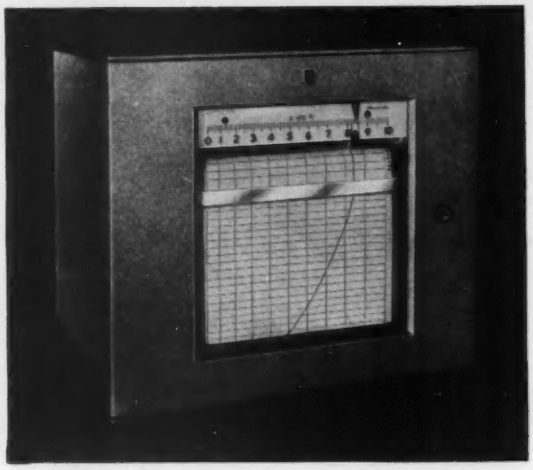
Then there is nuclear power. For a country like ours this new resource seemed a most opportune deliverence. After the Suez crisis there was more than one cry of expectant relief from those who foresaw British independence of foreign hydrocarbons. All was praise, in those days, for the Government's heavy investment programme. The nuclear bubble, so proudly blown so short a while ago, has certainly not burst, but its irridescence no longer dazzles the eye.

Clearly, the rise and fall of industries must affect the country's demand for labour and the kind of labour that is demanded. As one might expect, a need for the class of highly trained technologists seems to be acknowledged mainly in those industries where progress is being most vigorously made. Such industries were, and still (tenuously) are, those devoted to aviation and atomic energy. But in many places elsewhere the value of graduate engineers is just not noticed. Too many of the enterprises in this land, where once there was an industrial revolution, stay marvellously unmoved by the advances of their remoter relatives. Pressure to keep up with the Joneses is apparently only effective with nearest neighbours. Yet, in spite of this, there does seem to have been a good deal of beneficial cross-feeding. Thus some of the work of the aircraft people has percolated down to others, and their new techniques and materials have changed the complexion of more than one product. And radioactive substances would still be costing the earth if the atomic bomb had never been conceived (though the earth may be literally the price we shall pay).

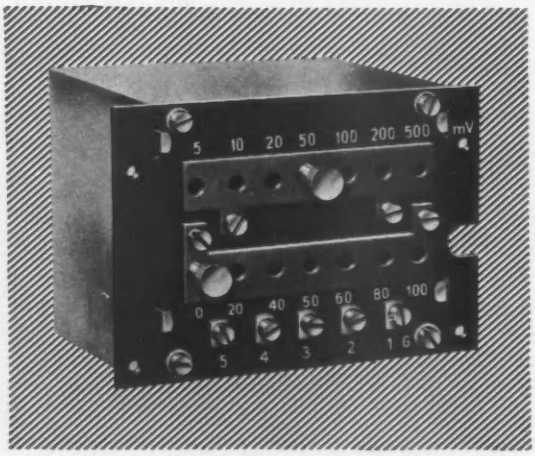
What is the significance of these things? It looks as if some of the lessons that have been learnt about economics may apply also to the flow-dynamics of ideas. Western countries seem to have seen clearly the implications of the great booms and slumps of a few decades ago. They know now that oscillatory transients as well as steady states are possible in an economic system—and that instability can be disastrous. To smooth out divergent fluctuations, they have discovered, judicious action is required of their governments. Perhaps something similar may be found necessary to control the ebb and flow of technological activity. Possibly we have been witnessing something that is obscured in the official statistics, namely just such an oscillation in our technological manpower resources as we see occasionally in the European and American economic systems. Because too much of British industry is tardy in its employment of trained men, it may be necessary for the state to subsidize what is on a profound view not very valuable work, in order to stimulate the country's technology enough for progress to be kept up in a fiercely competitive world.

Now that a period of damping is over, the time has surely come for a more energetic boost. The Minister for Science should be wary of the statistics. To get things moving the Government should still let contracts in whatever fields appear to be most glamorous at the moment. If there is any argument for it at all, here may be one for an ambitious British research on space travel. (This is of course quite the reverse of the conclusion reached by the Advisory Council.) There are no doubt better and more urgent uses for technical skill, but employment in a free country is not compelled. Progressive ideas must be taught by example. What, we wonder, are Lord Hailsham's plans?

* See this month's *News Round-up* for details



Easy to change the measuring range in this potentiometric recorder by PHILIPS



Range-changing unit. Top rail *permits choice of seven measuring spans from 0-5 mV upwards.* Bottom rail *provides seven zero-point positions up to 100% full scale. Clear, visible indication always.*

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LETTERS to the EDITOR

Any better?

SIR: Although I like CONTROL, I think it could be improved in one respect. The features themselves are very good, and on the whole you manage to balance the subjects quite well. But why do you mix up the advertisements with your articles and letters? I admit (grudgingly) that the advertisements are (sometimes) useful, but I do not read the magazine for their sake, and I do not like to have them pushed under my nose. When I look at them I want to do so voluntarily. I feel sure that many other readers will agree with me.

Basingstoke, Hants K. J. HALL

● *As you see, we have now changed our layout, and henceforward both 'Publisher's Piece' and 'Letters to the Editor' will share a page.*—EDITOR

How much droop?

SIR: I notice in your issue of November 1959 that Dr. Morley has made a reference to one of our simulator studies. He has, however, failed to make clear that the case considered was idealized to the extent that isochronous governing was assumed, the object being to isolate the effect of the hydraulic clutch. The actual governors are drooped and so the problem as illustrated in Fig. 3, Page 96, does not arise in practice, nor has it been found necessary to fit a 'stabilizing element'. I point this out in case some discerning reader should be tempted to comment.

Westland Aircraft Ltd. J. M. HARRISON

● *Dr. Morley writes: 'I should have made it clear in the section of my article headed "Twin Engine Considerations" that the simulator governors in the Westland rig, the results from which I was privileged to quote, were in fact isochronous governors. In practice the speed control system would have droop, which would materially alter the load-sharing problem and help prevent any large disparity during load changes. Mr. Harrison had kindly pointed out also that this particular test was not representative of practice on account of the governors; but if the isochronous characteristics had proved acceptable then actual governors with droop would have been even more so.*

In present day helicopters flown more or less conventionally, there is no special need for very close rotor speed control. The rotor R.P.M. are well up the speed range, the rotor inertia is high, and a nominal droop appears to be a satisfactory means of stabilizing the speed control. On the other hand if the machine is to be flown more automatically, using the rotor speed as the sensing element for the power control, over a wide power range, I believe it would be necessary to minimize droop. I also think that some form of load sharing device would be wanted to ensure full use of the available power under critical conditions.'—EDITOR

Light relief for students

SIR: Shortly, I shall be giving a course of lectures on servomechanisms and automatic control. I thought it might be a good idea, by way of a little light relief, to show a film or two on this or allied topics. I should be very grateful for any information you can give as to the availability of such films (or slides).

Cheadle, Cheshire E. ROSE

● *We agree that this is an excellent idea. Some possible sources you might try are: Aims of Industry Ltd., 5 Plough Place, London, E.C.4; Brook Motors Ltd., Empress Works, Huddersfield; Central Film Library (C.O.I.), Government Building, Bromyard Avenue, London, W.3; G.B. Film Library, 1 Aintree Rd., Perivale, Middlesex; Scientific Film Association, 3 Belgrave Square, London, S.W.1; Shell Film Unit, Norman House, 105 Strand, London, W.C.2.*—EDITOR

Academics not so weak

SIR: In your December issue Staffman brings to our notice a remark by Wing Commander E. W. Anderson, the President of the Institution of Navigation. To quote again, 'the main weakness in navigational thinking, particularly on the academic level, is the divorce of the flying control of an aircraft from its positional navigation'.

This is not so at the College of Aeronautics, where for several years we have been educating post-graduate aircraft and instrument engineers in the philosophy of integrated design, in which all feedbacks are not only recognized, but as far as possible, optimized. In addition to the normal two-year Diploma Course, the Dept. of Aircraft Electrical Engineering run a one-year course which is primarily aimed at providing the qualified control engineers which we on the academic level, and the Wing Commander, consider so vital to the aircraft industry.

In further support of the academic, an automatically guided aircraft system was reported in September's CONTROL; aptly enough being developed by another Division of Wing Commander Anderson's own firm, Sperry. CONTROL later reported in the following month's issue that this system originally formed the basis of a research thesis carried out in the above-mentioned department. This should go a long way to meet the President's criticism, so may we presume that it was some other academic level to which he was referring, or indeed that the fault is not an academic one at all.

College of Aeronautics K. C. GARNER

PUBLISHER'S PIECE

Arrival and departure

A number of readers have taken the trouble to compliment us on the Buyers' Guide that we published in our last issue of CONTROL. *The Guide was perhaps the* chef-d'oeuvre *of David Rayner, who has been on the editorial staff of the magazine since it was conceived. Rayner is making this both the climax and the conclusion of his journalistic career so far, for he is leaving us and going back into industry. We are very sorry to lose him, but we feel sure that he will make an excellent job of selling computers. To fill the vacancy we have gained the services of Paul Newnham, until now with the G.E.C.*

We think it good policy to get our new blood from such sources. The editors in their various grades are of course technical men, at present working on the very important task of information-spreading. While they try not to lose touch with the engineer on the job—and succeed remarkably well—it still helps to have new men straight from practice in the field. We think that Rayner and Newnham will each bring an invigorating freshness to their new work, and we wish both of them well.

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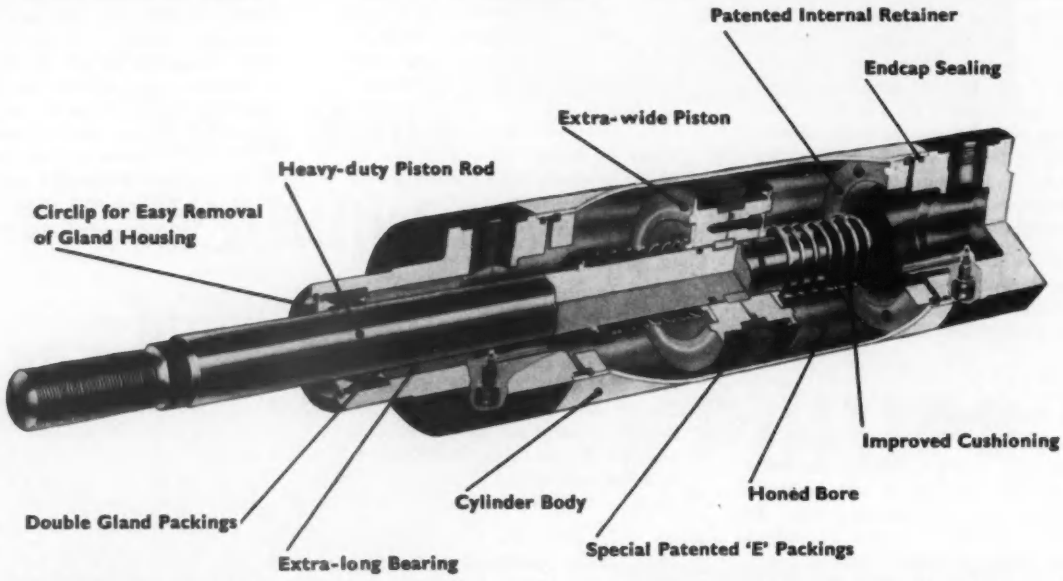

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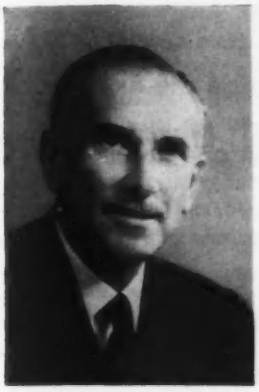


INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

Electronics is now reliable and optics offers accuracy says Hilger & Watts' Chairman and Managing Director, George A. Whipple, in . . . .

OPTICS AND ELECTRONICS FOR CONTROL

One of the main advantages to be derived from the use of electronics in process control is that a wide range of optical detectors can be used for measurement. Interpretation can readily be either analogue or digital. The first essential of control is to measure, and optical methods of measurement (by which I mean any method of measurement using electromagnetic waves in a wide band from 10 cm through to the X-ray region) are non-destructive, rapid, sensitive, free from mechanical wear, of low torque and inertia, and provide high resolution.

The more accurate and highly resolved the measurement, the finer the control that is potentially possible, and this is an important consideration when tight control of quality is necessary. Until recently, optical instruments relied upon the eye for 'detection', and this has been a handicap in transferring them from the laboratory to the automatic control of industrial processes. With the introduction of photo-conductive, photo-voltaic and photo-transistor techniques this is no longer the case. Instruments which employ discriminators sensitive to variations of refractive index, differential colorimetric absorption, variation in polarization, etc. are now available for plant control.

There is one important difference between laboratory instruments and those intended for industrial process control. The laboratory normally needs a versatile instrument, capable of high resolution over a wide range, which is operated under controlled conditions and by skilled hands. The industrial device is usually relatively coarse, and of limited range, since the user is concerned in the main with the ratios one to the other of certain specific elements. The industrial instrument differs from its laboratory counterpart in that it must operate continuously and under conditions quite foreign to the laboratory. It must need the minimum of maintenance despite the dirt, vibration and range of temperature variation found commonly under plant conditions.

The designer of optical instruments is now capable of meeting both the research need for refinement and the industrial requirement for 'ruggedization'. When electronic equipment was first introduced into industry it was a by-word for unreliability. The industrial engineer, therefore, called for mechanical and pneumatic solutions; techniques with which he was familiar and which he understood. To-day transistors are proving reliable, components are well-tried, and the failure rate is low.

Optical measurement always has been relatively 'bug-free', and the marriage between optics and electronics is breeding sturdy children. For this reason, I do not entirely agree with David Pinkney, in the July 1959 issue of CONTROL, when he says that electronics is the cast-off of the communications industry. Electronics is now an integral part of reliable modern instrumentation; photo-electricity not only makes possible a higher accuracy of control in industrial processes than is usually required, but is highly reliable. Electronics is no monopoly of communications, for it has given the plant engineer many methods of measurement and control in continuously working process plants. Even if, in a steel plant for example, a sampling technique must be used for analysis, up to thirty elements can be determined in five minutes by the use of photo-multipliers backed by reliable electronic circuitry—and the resultant analysis printed or punched on cards or tape—compared with as many or more hours required by skilled chemists in the laboratory.

Optics and electronics combine to form a team which cannot be ignored when considering future control techniques.

Geo. A. Whipple.

' Good in parts ' seems to be the judgment on 1959, but the year has left this country some urgent problems

The year behind us

by **H. H. ROSENBROCK, B.SC., PH.D., A.M.I.E.E.**
Constructors John Brown Ltd., Leatherhead

LOOKING BACK ON 1959, THE PICTURE OF CONTROL engineering is one of steady and unspectacular progress in the main, with one or two outstanding achievements which have caught the public imagination.

The high spots

The chief of these is undoubtedly the Russian success with two lunar rockets. The first, in September, landed on the moon while the second, in October, performed the even more difficult feat of passing behind the moon, photographing its unseen side, and subsequently transmitting the photographs by radio to earth. A comparable American achievement was the launching of a ' paddle-wheel ' satellite equipped with instruments to measure and transmit information on the radio-active conditions in space. In neither case has the guidance equipment been described in detail, so that the difficulties, and the means for overcoming them, can only be conjectured.

These are direct applications of military techniques, and it is true (and unfortunate) that in 1959 as in other recent years the overwhelming preponderance of research in control has been applied to military ends. The one civil application which can be compared in importance with them is the use for the first time early in 1959 of a digital computer to control a chemical process, a polymerization unit operated by Texaco. The computer was based on a military development by Thompson Ramo Wooldridge, and preliminary reports seem to show that the chemical application was technically successful and economically justified. Other rumours (in the absence of a decisive statement by Texaco) are less encouraging, but certainly the opinion in the United States on this subject is buoyant, and many other applications of the same kind are being made. In this country too a great deal of effort is being given to this field by computer manufacturers, and at least two of them have now announced special, all-transistor, computers for process control.

Measurement

Turning from spectacular applications to the foundations of control engineering, in measurement, there has been steady but slow progress. The time-scale for the development and application of a new measuring technique is usually five to ten years or more, and in one year there is consequently little fundamental change. It remains true to-day as in previous years that electrical measurements are often easy, other physical measurements are often possible, and chemical or ' quality ' measurements are often stubbornly difficult.

Some trends in measurement have been noticeable during the year (the selection is necessarily a random, personal one). The digital presentation of readings is becoming more common, especially where measurements must be often repeated. Examples range from laboratory balances to voltmeters, flow meters and spectrometers. This trend is intensified in the increasing number of cases where readings must be transmitted over a distance.

New principles of measurement follow a regular course from research laboratories into production control laboratories, and sometimes into instruments used for automatic control. In the chemical and process industries the last class now includes infra-red and ultra-violet spectrometers, refractometers and viscometers. Vapour-phase chromatographs are moving from control laboratories into automatic control and mass spectrometers will probably follow them. Many other promising techniques such as nuclear magnetic resonance, polarography and X-ray spectrometry are now moving out of the research laboratory. The United States has maintained and perhaps increased its lead over other countries in the embodiment of all these principles in commercial instruments.

Dynamics

After measurement, the second fundamental requirement is an understanding of the dynamics of the process which is to be controlled. In mechanical systems this seems never to have been a real difficulty. In aeronautics and in the field of nuclear energy much research has from the beginning been devoted to the problem, and computer simulations are regularly made. In the chemical and process industries, on the other hand, much less systematic effort has been devoted to the

problem. In some ways 1959 showed a setback in the last field. It has to a greater and greater extent become clear that routine design methods for investigating the control of distillation (for example) are not yet within our reach. Only the simplest control loops can at present be dealt with satisfactorily and until further decisive progress is made it remains doubtful whether the full (or sometimes any) advantage can be taken of new techniques in quality measurement or computer control.

Linear plains, non-linear foothills

In the theory of control the wide, fertile plains of linear theory are now fully colonized and have yielded a rich harvest of applications. The frontiers of exploration have penetrated the foothills of non-linear theory, and this is a much less hospitable country. Slow progress is still being made, but most of it comes from following valleys where the linear theory needs only slight modification—such are describing-function theory and systems with slowly-changing parameters. It remains true that in strictly non-linear situations (except the simplest) theory deserts us and we must revert to simulation.

This slowing-down of progress is probably only a temporary one, whilst suitable methods of advance are being devised. During the year interesting work on the problem was going on at a number of centres: at Cambridge on a machine for determining the statistical properties of control signals, at Imperial College on a non-linear adaptive filter, and at the National Physical Laboratory on 'learning machines'. The last two lines of work are related to 'optimizing control', in which the automatic controller adjusts itself to produce the best results from the process it is controlling. If such a device could be made to approach in efficiency to human abilities it would indeed be a complete answer to many problems. At present the machines are still inefficient in learning (often incredibly inefficient) and still vastly too large and expensive for most problems. Nevertheless a limited form of optimizing control may become common if digital computers are used to control industrial processes: such a computer could in theory carry out the process of 'evolutionary operation' devised by Box some years ago.

Control in industry

Events during the year included a conference in May on 'Instrumentation and Computation in Process Development and Plant Design', organized jointly by the Institution of Chemical Engineers, the Society of Instrument Technology, and the British Computer Society. This gave an opportunity to discuss automatic control and its application to industry. Some notable features of the conference were a theoretical paper by Kalman and others on means by which a digital computer could be used to control and optimize a plant, the description by Idzerda of a new type of ratio controller for flows, and a simple analogue computer for studying distillation columns which was described by Rijnsdorp and Maarleveld. Sir Harold Hartley gave the closing address and admirably surveyed the present condition of control and its future prospects.

Caution in the States

The I.S.A. show in Chicago gave as usual a conspectus of American progress. Compared with the show in Cleveland two years before, there was much less emphasis on data logging. Electronic instruments for process control were shown by all the major companies, but did not seem to be economically attractive at this stage either to users or to manufacturers. Computers for process control were being offered by a number of companies, but with a full admission of the difficulties — unfortunate experiences of some users with data-logging equipment have made this a difficult market. Analytical instruments for process control showed steady development. In all, the picture was one of cautious progress, though there was a feeling in the air that computer control was just round the next corner.

Russians coming up

Conditions in Russia are much less easy to assess than elsewhere, and the visit by a group of engineers sponsored by the I.E.E., and their subsequent report, was therefore valuable. Their general conclusion was that Russia at present lags behind this country in the application of control techniques. On the other hand a vast programme of research has been started, largely in the last two or three years. When this begins to bear fruit, our lead may rapidly disappear.

Faltering at home

Turning finally to the condition of control engineering in this country, 1959 has given little cause for satisfaction. The great need for increased educational programmes and better professional status is still unfulfilled (though a course in process control was started at Cranfield in September, and education and professional status were actively studied by the Society of Instrument Technology). Moreover, as a country we are failing to maintain our position in instrumentation and control. The development period for successful applications of control in industry is often five years or more, and the expenditure needed is more than many companies in this country can afford. In addition, when a new technique is at last established, the return is shared by many, and not only by the company which has borne the cost of development. Unless some solution can be found to this problem we shall fall further behind the United States, with its wide markets and large companies, and shall be overtaken by the intense centralized efforts of the Russians.

The year in a sentence

To sum up—a year of slow but steady progress in fundamentals, of spectacular achievement in a few fields, of exciting new possibilities still just beyond our grasp, and with an undertone of urgency in the problems confronting us as a nation.

A preview of the show

The forty-fourth Physical Society exhibition

THIS YEAR THE PHYSICAL SOCIETY'S annual exhibition—the 44th—promises to be more of a success than ever, in spite of the usual criticisms that the show has become too commercial. The exhibition will be held in the Old (Stands 1-50) and New (Stands 51-140) Halls of the Royal Horticultural Society in Westminster, London, from Monday 18 to Friday 22, January. The scope of the 'Phys. Soc.' is so wide that it is difficult to do more than describe the exhibition in the most general terms, but it is hoped that this preview will assist the visitor to find the wood among the many trees, without too much difficulty.

Analytical devices

Many instruments for spectrometry will be shown. A.E.I. (Manchester) will exhibit (Stand 123) probes for a high-resolution **nuclear magnetic resonance** spectrometer, and also a 2-in. laboratory **mass spectrometer.** A.E.I. (Woolwich) hope to demonstrate a production model **X-ray microanalyser** and 60 kV **X-ray fluorescence spectrometer.**

The U.K.A.E.A. will have much spectrographic equipment on Stand 86. A.E.R.E.'s Woolwich Chemistry Division will exhibit an automatic **atmospheric beryllium monitor** in which air is drawn through an arc, and the emitted light dispersed and measured by photomultipliers. A.E.R.E. will also show the automatic **recording of wavelength measurements** by the use of moiré fringes and photoelectric scanning. This equipment employs a Ferranti detector fitted to the base of a Hilger & Watts travelling microscope, and a N.P.L. 6250 line/in. grating. Dekatron counters are used and punched-tape print-out. Harwell's Isotope Research Division will show a **radio-isotope X-ray spectrometer** in which a source of X-rays excites fluorescent X-rays in the sample and these are analysed with a proportional or scintillation counter. Cambridge Instrument (Stand 97) will discuss their **scanning electron probe microanalyser.** In the latter, electrons irradiate the sample and the resulting X-rays are analysed.

The Admiralty Materials Laboratory (Stand 40) are to show a **curved-crystal X-ray spectrometer** which provides higher resolution than the flat crystal type and yet is adjustable for wavelength by simple means.

Various analytical instruments will be exhibited on Stand 139 by the Medical Research Council. These include a **mass spectrometer** for continuous gas analysis inside the lung; a scintillation counter for gas liquid **radio chromatography** which measures the radio-activity of organic vapours from a gas liquid chromatograph in parallel with normal chromatographic recording; centrifugally - accelerated **paper chromatography** for developing paper chromatograms in 10-20 min; and a **polarograph** for the measurement of oxygen concentration and rate of oxygen utilization in bacterial and enzyme systems.

Unicam Instruments will demonstrate four new models on Stand 87, a prototype flat-bed recorder for spectroscopy; the SP.100 **infra-red spectrometer**—a prism/grating double monochromator instrument; the SP.900 **flame spectrophotometer;** and a prototype recording **spectrofluorimeter** built from separate spectroscopic units to offer flexibility of construction.

The Physics Department of the University of Reading (Stand 134) are to show a **student's grating spectrograph** for teaching undergraduates. This has a 15,000 line/in. grating and is built of removable sections. Optical Works Ltd. (Stand 120) will show a small quartz spectrograph for student or factory use.

The Solartron **vacuum-dome X-ray spectrometer,** which can be linked with a manufacturing process to provide continuous analysis, will be on Stand 94.

An extensive range of analytical instruments will be shown by Hilger & Watts on Stand 95. The range includes a prototype **process control photometer** for measuring fluorescence and the absorption and scattering of light in a flowing liquid; a photoelectric microptic **polarimeter;** the Ultrascan recording **spectrophotometer;** and a simple and inexpensive grating monochromator.

On Stand 8, Perkin-Elmer will exhibit an **infra-red spectrometer** for the 12·5-25 μ region, **gas chromatography** equipment and a recording ultra-violet and visible **spectrophotometer.** Optica United Kingdom (Stand 69) will show a double-beam ratio-recording reflectance spectrophotometer, for fundamental colour measurement, and an atomic absorption spectrophotometer which was initially developed for the biochemist interested in small quantities of magnesium in serum. Joyce, Loebl, who are also on Stand 69, will exhibit the Chromoscan universal recording and integrating reflectance **densitometer** for chromatographic analyses, and a microdensitometer.

Doran Instrument (Stand 105) will show an **auto-titrator** for automatic titration in the 0-14 pH or -200, 0, $+1200$ mV ranges, **pH meters** and a **conductivity bridge.** Baird & Tatlock (Stand 127) will demonstrate their Analmatic **auto-titrator** for process monitoring, a wide-bore **polaragraph** for dissolved oxygen in water, and a **gas analyser** for the automatic measurement of hydrochloric acid in air. They will also exhibit a **centrifugal chromatograph,** gas/solid chromatography apparatus (Janak), and a multiple **Geiger-counter chromatogram scanner** for the simultaneous determination of radio-activity along 31 equal area adjacent strips of a chromatogram.

The Wool Industries Research Association (Stand 44) will exhibit an assembly for the automatic **chromatography and assay** of mixtures of radio-active substances. This collects fractions of the effluent from a chromatographic column and presents them in turn to a Geiger counter and records the counts obtained.

On Stand 93, W. G. Pye will demonstrate the **argon chromatograph, pH**

equipment and an **automatic titrator-controller** of new design. The latter features two independent electronic relay circuits, either of which can operate at any point in the 1 mA current range—e.g. 0-10 pH.

The continuous monitoring of sodium in liquid samples drawn from pipe lines is the duty of Evans Electroselenium's **recording flame photometer** to be shown on Stand 13. The R.31 **refractometer** of Bellingham and Stanley (Stand 107) is also a pipe-line instrument and may be employed to signal whenever a predetermined concentration is outside limits. The R.320 refractometer is intended mainly for use in the ultra-violet, and is an attachment to a direct reading wavelength spectrometer employed as a monochromator.

The Cavendish Laboratory of the University of Cambridge (Stand 136) will exhibit an **automatic single-crystal diffractometer** which makes the collection of accurate intensity data by counter techniques comparable in speed and convenience with photographic methods. Two circles carry counter and crystal respectively. An Edsac II digital computer feeds the instrument directly, giving the absolute crystal and counter positions for each reflexion.

The Coal Tar Research Association will have an **emissivity detector** on Stand 44, which detects the concentration and chemical structure of organic vapours in coal gas by measuring the variations in luminosity of the flame. Hanovia Lamps Division of Engelhard (Stand 45) have a **benzole meter** to indicate the efficiency of benzole recovery from coal gas. Its operation depends upon the selective absorption by benzene, toluene and xylene of ultra-violet radiation.

The **plant stream gas analyser** of Mervyn Instruments (Stand 99) will measure and record the amount of one component in a multi-component gas stream. This is a conductivity measuring device. Mervyn will also show a **square-wave polarograph,** a transistorized self-balancing **potentiometer recorder,** and a **sulphur-dioxide recorder.**

Newport Instruments (Stand 89) will exhibit an **electron resonance spectrometer** which operates at 9500 Mc/s and 150-8000 gauss, and is intended for routine chemical analysis of free radicals.

Data processing and ancillaries

A wide variety of data handling and presentation equipment will be on view. N.R.D.C. (Stand 31) will show a **digital voltmeter** having a pulse shifting circuit using ferrite cores and an analogue multiplier using piezoelectric crystals. The Medical Research Council (Stand 139) have simple **analogue-digital converters** with display and print-out facilities. These are based on moving-coil movements with the pointer replaced by a digital arrangement, and an electrostatic cogging system providing step-like movement.

The Admiralty Surface Weapon Establishment (Stand 40) will demonstrate **high-speed symbol writing.** Transistorized circuits employing pulse techniques enable the display of symbols on a c.r.t. at over 100,000 ch/sec. They will also exhibit a **digital data recording** system which records 12 channels to $\pm 0{\cdot}1\%$ at up to 20 readings/sec; and an **automatic film analyser** in which a photocell assembly scans trace records on film. The displacement of the trace from a datum is presented in digital form by linking the photocell lead screw and a shaft digitizer.

The various Ministry of Aviation Establishments will share Stand 1. R.A.E. Farnborough have a **voltage-to-digital converter** with a stable reference-voltage unit for feeding highly accurate real-time data down a telemetry link. This can take up to 6000 independent readings a second. R.R.E. Malvern have ferromagnetic films for **computer storage,** and the Rocket Propulsion Establishment equipment for **digital recording and analysis.** The analogue-digital conversion in the latter is performed by comparing the amplified value of a transducer signal with a ramp wavetorm.

The Computer Division of Elliott-Automation (Stand 116) will demonstrate **magnetic wire matrix storage** using transistorized logical elements, and the Miniac and G-PAC **analogue computers,** both Mark II developments. Elliott's will also show **potentiometer drives** and **servo multipliers** and a solid-state **analogue-digital converter** with a 12-bit resolution.

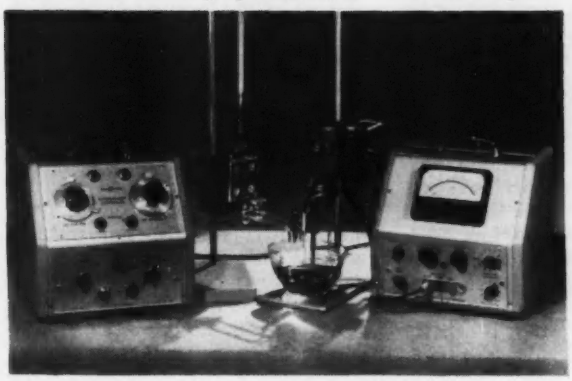
The A.E.I. companies on Stand 123 will demonstrate a **Hall-effect analogue multiplier,** an experimental **digital differential analyser,** and 1 Mc/s digital circuits for data processing operations. A.E.I. will demonstrate a **16-point data logger** consisting of a multi-point recorder fitted with a shaft digitizer.

Ferranti, on Stand 26, will exhibit a **digital voltmeter** covering 0·01 V–999 V, and the new MD5 **magnetic drum** which has a storage capacity of 160 tracks each holding 128 words of 50 bits. Fast transistorized circuits for the Ferranti **Atlas digital computer** will be shown.

A pulse width modulation system of **magnetic tape recording** of data from an Emiac II analogue computer will be demonstrated by E.M.I. Electronics on Stand 38. Peripheral equipment used with **Emidec digital computers** will be shown.

Solartron on Stand 94 will exhibit new **servo multipliers** and resolvers, **diode function generators** and a **logarithmic amplifier** from their analogue computing range. They will also show **digital voltmeters,** a **data amplifier,** an **analogue-digital converter** and a **digital data recorder.**

An **analogue-digital converter** by Dobbie McInnes (Electronics) on Stand 14 is a self-contained relay type unit with a fixed conversion time of less than 480 ms. Lintronic (Stand 41) have a high-speed analogue-digital converter which is capable of converting analogue signals at a rate of 10,000 conversions/sec. G.E.C. (Stand 115) will exhibit a prototype **inductive position digitizer** which requires low input torque and can give remote in-



Automatic titrator controller with pH meter. The autotitrator has two independent electronic relay circuits each of which can be set to operate at any point in the 1 mA range—e.g. 0–10 pH (W. G. Pye & Co. Ltd.: Stand 93)

In this fully automatic titrator for process monitoring, titration is performed by a motor-driven syringe pipette coupled to a recorder pen. This model is for the determination of dissolved oxygen in water (Baird & Tatlock (London) Ltd.: Stand 127)

dication of the position of a rotating shaft either as a four-digit display or as binary-coded decimal output. **Data processing and logging equipments** by Hilger & Watts (Stand 95) employ coded scales for analogue-digital conversion. Burndept's **digital valve voltmeter** will be shown on Stand 29, and Racal's digital indicating instruments on Stand 17.

New Electronic Products (Stand 7) will exhibit a **magnetic tape system** for use with large-scale digital computers. This is interposed between the computer and the paper tape or punched card store to save computing time. Royston Instruments (Stand 10) will exhibit models of their Midas **magnetic-tape flight-data recording system.**

A **Ramey magnetic amplifier** used in the construction of logical elements will be exhibited on Stand 44 by the B.I.S.R.A.

Flow and level

The National Engineering Laboratory (Stand 44) has developed a **flow calibration rig** for determining the performance of oil meters and pumps. This is of the measured period type in which oil is fed to a tank until it obscures the light to first one and then a second phototransistor level indicator.

The Medical Research Council (Stand 139) will exhibit a new swinging-gate variable-area-orifice **flowmeter.** This consists of a vane rotating centrally in a cylinder having a fixed radial partition. Fluid enters to one side of the partition and escapes through a peripheral annular orifice. The area of the orifice uncovered as the vane rotates is proportional to its angular deflexion and thus to flow rate.

British Scientific Research Association will show their **ultrasonic flowmeter** for 'difficult' liquids on Stand 77. Developed for N.R.D.C., this device operates by comparing the phase of ultrasonic signals transmitted with and against the flow. Transit is more rapid in the direction of flow than against the flow, so that a comparison of transit times gives the rate of flow.

Lintronic (Stand 41) will exhibit several devices of flow interest. Their **two-film yaw meter** is a yaw probe with two platinum films coated on its leading edge, which are spaced at 120° to each other and connected to form a bridge circuit. When the probe points upstream the bridge is balanced; if it does not point upstream, an unbalance signal operates a servo loop to correct the probe's position. The Lintronic **flow transmitter** is a differential-pressure sensing device with a feedback system.

Dobbie McInnes (Stand 14), Townson & Mercer (Stand 82) and the Coal Tar Research Association (Stand 44) will be among those showing **viscometers.**

A **level indicator** to be shown by Panax Equipment (Stand 85) employs a caesium source to determine liquid levels in sealed containers. Burndept's (Stand 29) **proximity switch,** a capacitance-change device, can be used for level control on powders, fluids or granules, whether conducting or not, as well as counting, process initiation or temperature control.

The N.C.B.'s Coal Research Establishment (Stand 124) has a **bunker level indicator** which is of the proximity probe type, but non-electronic. Its principle is that a low-pressure low-flow air current in a 2-in tube may be diverted when the tube opening is obstructed to another channel incorporating an indicating device.

A **gamma-ray level indicator** by Salford Electrical Instruments (Stand 22) was originally developed for the N.C.B. to provide remote indication of the level of coal within bunkers. It can, however, be used for various other industrial applications involving solids or liquids.

G. V. Planer (Stand 53) will exhibit an unusual **mercury switch** which provides continuous response to angle of tilt. The device incorporates film resistor patterns, and as the mercury takes up a position depending on the angle of tilt, so will the output vary in response.

Pressure

New Electronic Products' (Stand 7) range of differential inductance **pressure transducers** includes a single-ended transducer which incorporates all four arms of the bridge, thus allowing the use of long (200 yards) unbalanced cables. The range extends from 0–5 lb/in² to 0–2000 lb/in².

The N.C.B.'s Mining Research Establishment (Stand 124) have developed a **pressure regulator** which will maintain a flow of butane gas of about 10 ml/min to an accuracy of ± 1%. This is a diaphragm regulator with a special valve.

Several organizations have produced pressure-measuring devices of medical interest. The Medical Research Council (Stand 139) will exhibit a transistorized miniature **capacity pressure-gauge** system which has a diaphragm of aluminized Terylene. A f.m. oscillator and discriminator circuits are housed integrally with the gauge. Their pressure- or temperature-sensitive **telemetering transmitter,** which is capable of being swallowed for measuring temperatures and pressures in the digestive tract, will also be shown.

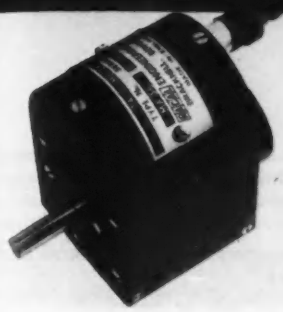
A.E.I. (Stand 123) have an **electronic pulsometer** for measuring blood pressure during surgery. A microphone picks up the patient's fingertip pulse and feeds it via a transistor amplifier to an output meter. A manometer is incorporated and, when an occluding arm cuff is used, systolic blood pressures can be read at the point where pulse indication disappears on the output meter.

Edinburgh University and S.E. Scotland Regional Hospital Board (Stand 135) also have a **pulsometer** for measurement of systolic blood pressure. They will also exhibit two drift-free **recording manometers**: one records the pressure in a system by measuring the flow rate of a liquid between a known pressure system and the unknown system, the rate being determined by a drip recorder incorporating a photo-transistor; the other uses a simple photo-transistor-controlled servo system, the level of liquid in one arm of a U-tube being held by raising or lowering the arm. A clinical **blood-pressure recorder** will be shown which records from a cuff which is automatically inflated every 90 s. The **foetal pulse rate monitor** uses a vibration pick-up in which movement of a grating alters the light falling on a photo-transistor.

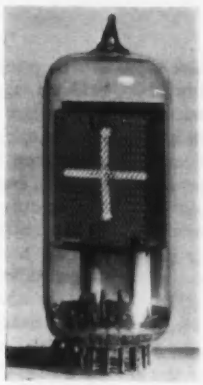
Pressure transducers of the unbonded resistance bridge, vibrating cylinder and potentiometric pressure types will be exhibited by Solartron (Stand 94) together with a **pressure scanning valve.** The latter is a multi-pressure line commutator which permits one transducer to sense pressures at a number of points sequentially.

Salford Electrical's (Stand 22) **remote indicating system for pressure measurement** with long-scale indicator consists of an electromagnetic transducer and remote a.c. dynamometer. A Bourdon tube or diaphragm may be used. Salford will also show a remote indicating recorder which consists of a transducer responding to pressure, displacement or level, together with a special Honeywell Electronik recorder.

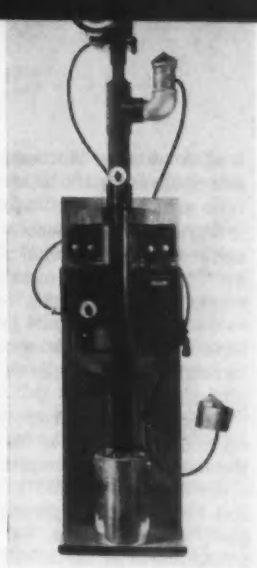
J. Langham Thompson (Stand 47) will exhibit **pressure transducers** of the new potentiometric type, covering 10 in. water gauge to 10,000 lb/in². A.E.I. (Stand 123) will show a combined **Penning/thermocouple gauge** control unit, the thermocouple gauge covering 1 mm mercury to 10^{-2} mm mercury, and the Penning gauge 10^{-3} mm mercury to 10^{-5} mm mercury. A.E.I. will also exhibit a **Pirani gauge** control unit for gas pressures below 1 mm mercury.



Transducer with 60-tooth rotor which rotates in a magnetic field to give 60 pulses/revolution (Racal Instruments Ltd.: Stand 17)

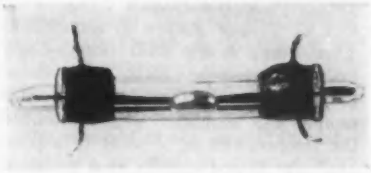


A Digitron gas-filled cold-cathode display tube in which stacked electrodes are illuminated to form characters (Ericsson Telephones Ltd.: Stand 104)



In this bunker level indicator an air current is diverted when the probe is obstructed (Coal Research Establishment: Stand 124)

The first of its type commercially available, this automatic adiabatic bomb calorimeter makes possible two or three determinations of calorific value of solid or liquid fuels in an hour. The control unit incorporates a Wheatstone bridge with thermistors in two arms (A. Gallenkamp & Co. Ltd.: Stand 46)



Integral film resistor patterns in this mercury switch provide continuous response to angle of tilt (G. V. Planer Ltd.: Stand 53)

Displacement and speed

A **position-sensitive photodiode** will be demonstrated by B.S.I.R.A. (Stand 77) in a test rig which evaluates these sensitive detectors for displacements of the order of a micro-inch. A spot of light is focused on the photodiode's sensitive area and when this spot is moved between the electrodes, the voltage output changes sign, passing through zero in the central position. Suggested applications in machine tool control are fringe counting and beam riding.

The Wayne Kerr (Stand 102) **distance meter** employs non-contacting probes for the direct and continuous measurement of distances between 50 μ in. and 0·5 in. to an accuracy of 2%. This is a capacitance probe device working into a transformer bridge, and will be demonstrated measuring the thickness of glass tubes with the aid of a magnetized probe and movable steel balls. The Wayne Kerr **electronic micrometer** will be demonstrated fitted to an optical microscope to measure objective movement relative to the slide platform.

The National Engineering Laboratory (Stand 44) have a **displacement gauge** for analysing continuous records, displayed on a c.r.t., of ram displacement and extrusion pressure obtained in an extrusion press. They have also designed a moiré fringe **velocity gauge** for measuring the variation in ram velocity of a shaping machine during cutting.

J. Langham Thompson (Stand 47) will show several new **transducers** for acceleration, displacement, force, pressure and vibration including an **accelerometer** for static and dynamic measurements within the range $\pm$ 1 g to $\pm$ 100 g. **Displacement transducers** for a maximum measurable displacement of 12 in. are now available, as are load cells and dynamometers for the measurement of forces up to 300 ton and 200 lb respectively.

Remote indication of **linear displacements** up to 8 in. is available from transducers to be shown by W. G. Pye (Stand 93). These operate as differential inductors, the output voltage being linearly related to the displacement of an iron slug.

Various instruments the operation of which depends upon a **differential displacement transformer** used in association with a proof ring, will be exhibited by the Research Association of British Rubber Manufacturers (Stand 44). These include a tensile tester for stress-strain measurements, a sinusoidal strain dynamic tester, a friction apparatus, a rope friction machine and an intermittent stress relaxation apparatus.

An **indium antimonide displacement transducer** by N.R.D.C. (Stand 31) will detect 1A movement. The semiconductor is supported in a magnetic field gradient so that any displacement of the semiconductor is accompanied by a change in its resistance. The indium antimonide unit is in a Wheatstone bridge whose arms lie in a magnet gap. Movement of the magnet unbalances the bridge, the output of which is amplified to give a measure of mechanical displacement.

N.R.D.C. will also exhibit a **tachometer,** for operation down to 0·1 rev/min. This determines the speed of rotation of a conducting structure by observation of the magnetic field resulting from circulating currents induced in a member rotating in a primary field. The induced field is observed by means of a second harmonic flux detector, a null being obtained by opposing the induced field with a field from a feedback winding.

Shaft speed in rev/min. is provided by Racal's (Stand 17) electromagnetic transducer feeding a digital counter. This consists of a rotor with 60 teeth rotating in a magnetic field to give 60 pulses/rev. If insufficient torque is available, a photoelectric transducer can be used and, for high accuracy, a coaxial magnetic transducer. **Rev/min. indicators** by British Physical Laboratories (Stand 20) consist of a transistorized monostable oscillator triggered from a motor car's ignition.

A **rate-error sensor** by Ericsson Telephones (Stand 104) is basically a transistorized tachometer in which is incorporated a device for sensing that the rates lie within limits. Covering 0-99,999 it has a time base variable in 1 ms steps from 0-0·999 s.

Temperature

A new thermometer by the National Engineering Laboratory (Stand 44) is for precise measurement under indus-

trial conditions. Accuracy is 0·001 °C and it covers 0–100 °C. A transformer ratio arm bridge technique is used.

Shirley Developments will exhibit a **surface pyrometer** on D.S.I.R.'s Stand 44. This is for measuring the surface temperature of rotating rollers heated to 50-150 °C. Frictional heating errors have been overcome by covering the bimetallic strip with thin strips of p.t.f.e.

Engelhard Industries' Baker Platinum Division (Stand 45) will show **thermocouples** for temperatures of the order of 2000 °C (2800 °C in one case), and Cambridge Instrument (Stand 97) **pipe thermocouples** for measuring temperatures of up to 300 °C for pipes of a wide variety of diameters.

G.E.C. Research (Stand 115) will exhibit a prototype **thermocouple-signal digitizer** for monitoring the temperatures in the reactor cores of the G.E.C. nuclear station at Hunterston. This works in the 8421 binary-coded decimal system. Ekco Electronics (Stand 30) will show their **thermocouple trip amplifier** which monitors the temperature at a point in a plant and trips guard circuits at a predetermined level. A temperature trip range of 600 °C is provided, although this can be extended to 1000 °C. A.E.I.—ex Sunvic—(Stand 123) will demonstrate a **16-point data logger scanning thermocouples** and producing a tabulated log of input signals.

Townson & Mercer (Stand 82) will show a low-temperature **thermistor bridge controller** regulating a − 70 °C thermostat bath to give ± 0·05 °C control. The flow of cooled water through a heat exchanger is regulated to balance the heat gained through the Dewar vessels.

The Explosives Research & Development Establishment (Stand 1G) will show equipment for estimating the **calorimetric value** of propellants. The temperature of combustion of an organic compound is measured by a platinum resistance thermometer in conjunction with a Smith's No. 3 difference bridge operated automatically by rotary solenoids. The bridge is continuously balanced against rising temperature by causing off-balance current to move a light spot on to a cell, the resulting photoelectric current being amplified to operate a relay. The latter switches power to a rotary solenoid to alter the bridge decades.

The U.K.A.E.A.'s Atomic Weapons Research Establishment (Stand 86) will show a **thermistor anemometer** and leak detector whose operation depends on the cooling of an electrically-heated thermistor bead. Variations in thermistor resistance, caused by changes in air velocity past the bead, are detected by the unbalancing of a bridge.

Sangamo Weston will exhibit two test equipments of some temperature interest on Stand 96. The **jet pipe temperature test set** checks gas-turbine temperature-control equipment by injecting current into the engine thermocouples to simulate temperatures between 500 °C and 900 °C. The Sangamo Weston aircraft ice warning system, which consists of a resistance bulb, detector head and control unit, can be checked by the **ice-detector test set.**

Servos and ancillaries

The prototype of a comprehensive **transfer function analyser,** type 46, will be exhibited by Servomex Controls on Stand 11. Rotating synchros generate the sine wave and multiply the measured signal by the fundamental frequency. The multiplier produces two outputs, one proportional to the real part and the other to the imaginary part of the measured signal. Phase reading is accurate to ± 1° and amplitude reading to ± 2%. Servomex will also show a **servo-operated speed controller** for up to 0·5 b.h.p. Servomex associate Feedback Ltd., will exhibit a **servo system** for demonstration and student use, a **servo analogue demonstration** of that system, and **analogue demonstrations** to illustrate principles of root locus analysis.

Elliott-Automation's Servo Components Division (Stand 116) will show examples from their range of 26 V 400 c/s size 08 **synchros,** size 11 stub synchros, two-phase a.c. **servomotors** in size 08, 10 and 11 housings, high-torque low-inertia size 08 p.m. d.c. (6 V–28 V) **motors,** size 11 (28 V) p.m. motors, and a new size 11 Mark II low inertia p.m. motor. The latter has a rated speed of 5000 rev/min, a rated torque of 130 g cm and a stall torque of 400 g cm. They will also exhibit Holtzer-Cabot industrial control **servomotors** and induction or synchronous motors, and **torque motors.**

R. B. Pullin (Stand 72) will show examples from their range of low-voltage wound-field a.c. and d.c. **motors** and a new range of p.m. d.c. motors in International frame sizes. Their a.c. servo components include size 11 and 18 **synchros,** size 11 **resolvers,** size 10 motor and **motor generators,** 15 and 18 motor generators, **transistor amplifiers** and magnetic output transformers and **gearboxes** for servo systems.

Servo system analysis is one of the applications of a very low frequency (10 mc/s to 100 c/s) **function generator** of Advance Components (Stand 9). Waveform generation is of the optical-mechanical type, a narrow slit of light being scanned by a rotating disk which has an opaque area corresponding to the required function.

Components, including semiconductors

As is only to be expected, a great deal of space will be devoted to semiconductors of one form or another. The G.E.C. Semiconductor Division's (Stand 23) display includes germanium gold-bonded **diodes,** silicon variable capacitance diodes, **silicon zener diodes,** high voltage **silicon rectifiers,** a new range of **silicon controlled rectifiers,** germanium low frequency **transistors** and high-speed switching transistors. G.E.C. Research (Stand 115) will exhibit a prototype **digital display tube.** They will demonstrate the measurement of **thermal diffusivity** in which a temperature wave is generated by means of the Peltier effect at the junction between a *p*-type and an *n*-type semiconductor.

Ferranti (Stand 26) will exhibit new **silicon semiconductor devices** including pnpn signal **diodes** and **triodes,** pnp and npn signal **transistors, variable capacity diodes,** silicon power **rectifiers** and **photocells.** Ferranti will demonstrate power control by pnpn devices, **photo-voltaic-transistor reading** of punched or dotted cards and a silicon photo-voltaic sensing element as a trigger for a heavy current system.

Ediswan Mazda semiconductor devices will be displayed on Stand 123 by A.E.I. (Woolwich), and A.E.I. Research will demonstrate **silicon-controlled rectifiers** and **silicon transistors. A dew-point hygrometer,** to be demonstrated, employs a refrigerating *p*-type and *n*-type bismuth telluride thermocouple to cool a mirror so that dew is formed and may be detected optically. A control unit switches the current on and off as dew forms and evaporates, to provide continuous operation.

S.E.R.L., Baldock, will exhibit **gallium arsenide** semiconductor material on Admiralty Research Stand 40. Rectifiers of this material will operate at 300°C and room-temperature devices can be much smaller than devices of other materials. Switching diodes have been made with a transition time approaching two millimicroseconds.

The demands of transistor circuits have led to the development of microminiaturization at R.R.E., Malvern (Stand 1A). Initially it is hoped to scale down conventional transistor circuits by at least 10:1 in both size and weight. Glass is used as the circuit substrate, although ceramic is preferred, and components consist of thin films deposited by vacuum evaporation. Resistors consist of thin nickel-chro-

mium films, and capacitors are made as sandwiches of thin metal films with magnesium fluoride as the dielectric. Transistors and diodes are fabricated as flat units.

Sangamo Weston (Stand 96) have developed a **transistor relay,** primarily to replace the high-speed polarized relays in their tachometer computer box, although other applications are under consideration. The transistor relay cannot suffer from contact troubles. It consists of two transformers the secondaries of which are coupled to the base emitter circuits of two silicon transistors. The transformers are connected in reverse phase to each other so that one transistor is saturated while the other is non-conducting. The transistors are in series and arranged so that one charges a capacitor and the other discharges it through an indicator calibrated in terms of rev/min or frequency (50-300 c/s).

High-g relays by A.W.R.E., Aldermaston (Stand 86) have been designed to be immune to mechanical acceleration—either translational or rotary. They have functioned normally in centrifuge and vibration tests at peak accelerations in excess of 100 g in the frequency range 0-2000 c/s. Coil consumption is 1-2 W.

A **taut suspension galvanometer movement** will be shown incorporated in a recorder by Cambridge Instrument (Stand 97). In this system, the pivots and associated jewels of the conventional moving-coil instrument are replaced by short metal bands under tension, so that faults caused by pivot wear and damaged or dirty jewels are avoided. The suspension strips provide the moving coil with control force and electrical connexion, making a simple, strong and friction-free movement.

Three new **cold-cathode trigger tubes** for relay applications in low current circuits will be exhibited by English Electric Valve (Stand 121) together with a **glow modulator tube.** The output of the latter is 0·13 candle power at 30 mA cathode current and it has applications in facsimile, stroboscopes and photoelectric counters.

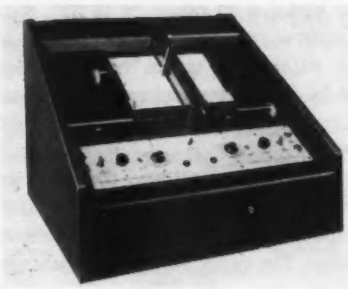
Ericsson Telephones (Stand 104) will exhibit **beam switching tubes**—Trochotrons, **Dekatrons** and gas filled **cold cathode register tubes**—Digitrons—for converting electronic signals or electro-mechanical contact combinations directly into readable characters. Among solid state devices to be demonstrated, will be **sintered cadmium sulphide cells** operating electromechanical devices. A wide range of **miniature relays,** including a low noise level chopper, will be shown by Ericsson's Electro-Mechanical Division.

Various instruments on Electronic Instruments Stand 91 employ the **Vibron vibrating-reed electrometer,** including three pH meters, a mass spectrometer amplifier, a flux scanning electrometer, and a logarithmic electrometer which covers 10^{-11} A to 10^{-15} A on a single scale meter without range switching. Two special Vibron amplifiers for use in vapour-phase chromatographs will also be shown. One of these is an ionization flame detector amplifier.

Among the many nucleonic equipments to be shown by Isotope Developments (Stand 34), is the **Vibreed 1880 dynamic capacitor electrometer** for measuring small direct currents in high-impedance circuits. Full-scale sensitivity is steplessly adjustable from 10-200 mV and this range, together with replaceable input resistors, permits current measurements over ten decades.

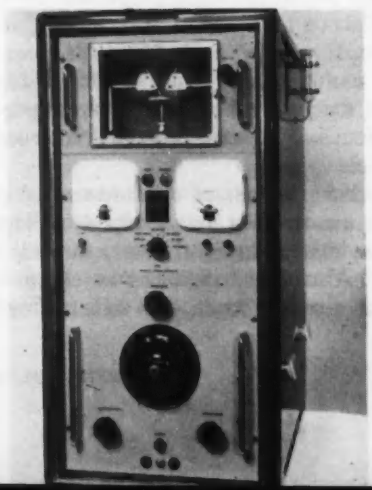
Three Discourses will be given during the Show, all at 5.45 p.m. On Monday, January 18, Flight Lieutenant J. Billingham of the R.A.F. Institute of Aviation Medicine will speak on **Some Reactions of the Human Body to the Stresses of High Performance Flight;** on Tuesday, January 19, Dr. L. Essen of the N.P.L. will discuss **Atomic Time;** and on Wednesday, January 20, Dr. D. A. Wright of the G.E.C. Research Laboratories will present a paper entitled **Recent Advances in Solid State Physics.**

The exhibits at this important exhibition are covered in much greater detail than is possible in a preview of this nature, in the Physical Society's Handbook of Scientific Instruments and Apparatus 1960. Available from The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7, at 6s. (8s. by post) it contains over 350 pages of information and has a reference value much greater than the average exhibition catalogue.



Full-scale travel in 200 milliseconds is claimed for this X-Y recorder
(Ekco Electronics Ltd.: Stand 30)

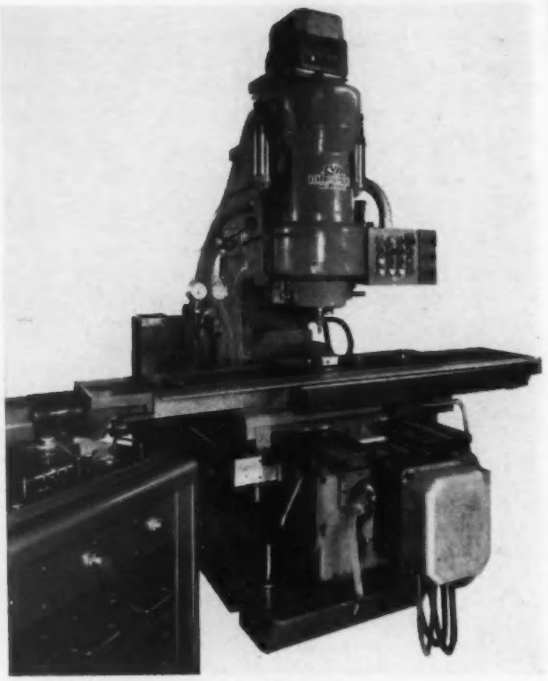
A beta-ray gauge measures the weight per unit area of hat bodies
(British Hat and Allied Feltmakers Research Association: Stand 44)



The international test for resistance to tracking is performed automatically by this comparator
(British Electrical and Allied Industries Research Association, and Southern Instruments Ltd.: Stand 44)

Automatic standardization is provided by this beta gauge
(Baldwin Industrial Controls: Stand 112)

Linear slide velocity is an important parameter in the control of many machine tools. Below is a review of some of the suitable electrical transducers



Milling machine with Ferranti control system

Linear tachometry for machine tools

by **M. J. C. FOWELL**, B.SC., A.M.I.E.E. *and* **A. COWLEY**, A.M.C.S.T.
Manchester College of Science and Technology

IN THIS ARTICLE WE DISCUSS SOME POSSIBLE METHODS of obtaining electrical signals, proportional to linear slide velocity in a machine tool, for the purposes of automatic control. The typical features of several methods are outlined and the relative merits and limitations of these are summarized.

ROTATION TO MEASURE LINEAR VELOCITY

One way of deriving a linear velocity signal is to use a mechanical linear-to-rotational converter, such as a rack and pinion, in conjunction with some method of measuring rotational velocity. Rotational velocity measurement methods are well known and are often based on some form of rotating dynamo-electric machine. Thus a small precision d.c. tachometer generator (*1*) with a permanent magnet field may, when lightly loaded, be used to produce a voltage output which is proportional to the shaft velocity, the polarity of the output voltage indicating the direction of rotation. Such systems have a useful velocity range which is dependent upon the safe mechanical speed of the generator and upon the commutator noise level. Accuracies of $\frac{1}{2}$ to 2% can be achieved (Fig. 1).

Similarly, an induction tachometer generator (*2*), excited from an amplitude-stable a.c. input, may give an a.c. output voltage the value of which represents the rotational speed, direction of motion being indicated by the relative phase of the output and input signals (whether the output signal is in phase or in anti-phase with respect to the input signal). Accuracies of the order of 2% are possible within the useful velocity range, which is determined by both safe mechanical speed and the available facilities for detecting the inherently low output voltage.

Another velocity indicating machine, the capacitor tachometer, an all-electric device (*3*), employs a commutator with a capacitor (or capacitors) connected across various segments. The capacitor system is charged through one set of brushes, and discharged through another set into an output circuit. The net amount of charge passed per second from the input to the output depends on the speed of commutation, and therefore on the shaft velocity, as in Maxwell's commutator bridge. The useful velocity range of this system will depend upon the minimum capacitor recharging time and the spurious noise level. Accuracies rather less than 1% are possible.

Further methods of measurement of shaft speed involve the detection by a photocell arrangement of variations in incident light from a striped pattern on the shaft. Also, if the shaft has an electro-mechanical resolver attached to it, the signals from the resolver

may be processed to give a velocity signal. These methods, however, are not specifically for the measurement of rotational velocity, and will be referred to later in relation to linear measurement methods.

Each of the methods discussed in this section involves the conversion of linear motion into rotation, and the hysteresis inherent in the converter has to be considered.

VELOCITY AND ACCELERATION TRANSDUCERS

Self-generating linear-velocity-measuring instrument

This instrument consists of a permanent magnet and a coil, either of which can act as the seismic mass. The instrument will measure linear velocities in horizontal or vertical planes, and generates a voltage proportional to the velocity of the object to which it is attached (Fig. 2). Available instruments can be used above their resonance, in which case the seismic mass remains substantially stationary. The useful frequency range in general extends from the resonant frequency of the seismic mass to about 1000 c/s, with less than 5% amplitude variation if the instrument is suitably damped. Sensitivities are within the range 50 to 150 millivolts per inch

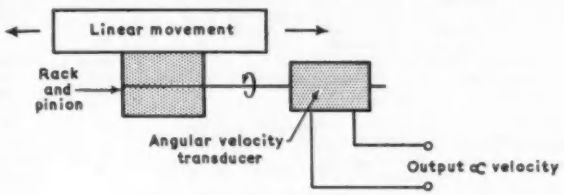


Fig. 1

per second. The usable range is limited by amplifier noise level and by the maximum stroke of the seismic mass. A typical upper limit would correspond to an acceleration of 35 g (100 in./sec at 25 c/s). The transverse response of these instruments is normally less than 5% of the axial.

Integrated linear acceleration measurements

Seismic-mass accelerometers are available with damped self-resonant frequencies between 100 and 500 c/s. These instruments can be used below their res-

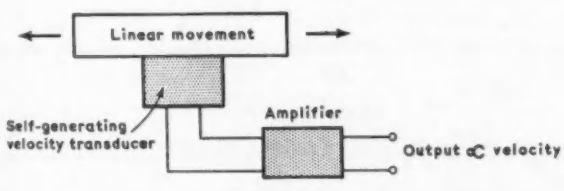


Fig. 2

onant frequencies to provide maximum outputs above ± 5g. Such devices will measure accelerations down to about 0·1 g.

These instruments can have resistive, capacitive or inductive pick-offs, and the acceleration causes variation in one of these elements. Instruments with capacitive pick-offs require to be energized by a carrier with fairly high frequency. The capacitance variation can be used to detune the carrier oscillator and provide a frequency-modulated signal; the signal is then demodulated and amplified, resulting in an output voltage proportional to acceleration. The sensitivity of such a system will depend upon the carrier frequency and amplification, whilst the minimum response will be limited by frequency stability and amplifier noise level (Fig. 3).

The chief disadvantage of this system would appear to be the cost of the auxiliary equipment required (approx. £150). Inductive instruments would require similar driving and detecting equipment. The response to transverse accelerations is generally less than 5% of axial. If this response is required to be of the order of 0·1% then inertial guidance accelerometers may be desirable (Price £250–£400).

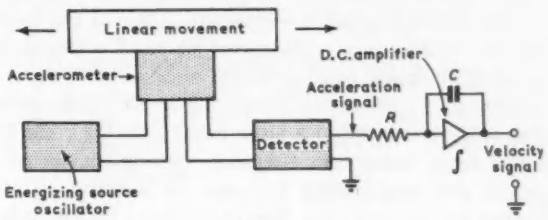


Fig. 3

Piezo-electric accelerometers

Self-generating piezo-electric accelerometers are available with self-resonant frequencies of several kilocycles per second and maximum accelerations above 1 g and up to 1000 g. The sensitivity of such devices is of the order of 10 to 50 millivolts per g. The minimum measurable acceleration of these instruments would depend upon amplifier noise level and would probably be approximately 0·02 g. A high input-impedance amplifier with low noise level would be required to provide useful output signals. Such amplifiers are available. The transverse response is normally less than 5% of the axial.

The voltage signal proportional to acceleration could be integrated by a standard a.c. coupled integrator to provide transient velocity signals suitable for velocity damping in a servo over part of the required frequency band. Such a system could augment a second velocity measurement based on pulse-rate monitoring if a digital measuring system is employed.

PULSE-RATE MONITORING SYSTEMS

If the position-measuring system is digital, then it may be possible to obtain one signal per incremental movement of the table. Such a signal would have a pulse rate equal to the number of basic increments of measurement per second, and the pulse signal may be processed to give an analogue output equivalent to the table velocity.

The analogue output is obtained (*5*) by transforming each pulse into a standard amount of electric charge. After smoothing, the charges produce a current which is proportional to the number of charges passed per second, and therefore to the rate of passage of the input

pulses. The process of smoothing introduces an exponential lag into the velocity measuring system.

Direction discrimination requires the employment of two input channels feeding a pair of balanced analogue devices. These devices have to be matched against each other for satisfactory working. In such a system, with a smoothing time constant which will be chosen from the point of view of optimum control system performance, the output ripple will depend upon the rate meter parameters, and will not decrease with decreasing output; in fact the reverse will happen (Fig. 5). The fundamental frequency component of this ripple is the pulse repetition frequency, and as this is lowered the various frequency components of the ripple will come successively within the bandwidth of the smoothing circuit and thus the effective ripple power will increase at the same time as the velocity signal is decreasing. Thus as the pulse rate input frequency is decreased we reach a frequency somewhere in the neighbourhood of the smoothing circuit bandwith where the further depression of the pulse frequency brings about a large increase in the noise-to-signal ratio. Below this frequency, the rate-meter output is not only useless but may be harmful to the control system operation. This is because a smooth velocity input will produce a jerky output signal which will be reacted upon by the system to smooth the voltage output—to the detriment of the output velocity. It is therefore considered necessary to remove the pulse-rate-meter output below a predetermined level. This can be done by means of a biased diode switch at the output terminal, though it would have to be arranged to cut off above the minimum usable signal because of peak noise.

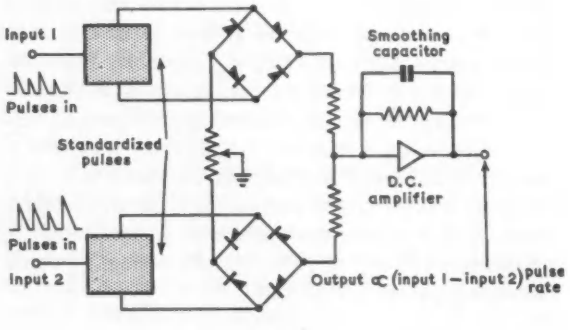


Fig. 4

A more complicated method involves the use of a secondary and less accurate pulse-rate meter, the output of which is used to gate the pulse signals to the primary pulse-rate meter and to cut the pulse signal off when the pulse rate is of less than a predetermined amount.

Overcoming low-pulse-rate difficulties

Suppose that a single low pulse-rate signal is fed simultaneously to both of the pulse-rate meter units of a balanced bi-directional system. This pulse rate will increase the count at either input and may be made high enough to ensure that operation is not rough. Each analogue voltage output is offset by an amount equivalent to the low pulse-rate input, and the pulse-rate meters have to be adjusted so that these voltages balance out for zero true signal injection (Fig. 5).

The main point to consider is the probability of the pulses on the two channels clashing. The probability of finding a pulse at any time on either the signal pulse or the auxiliary pulse channels is

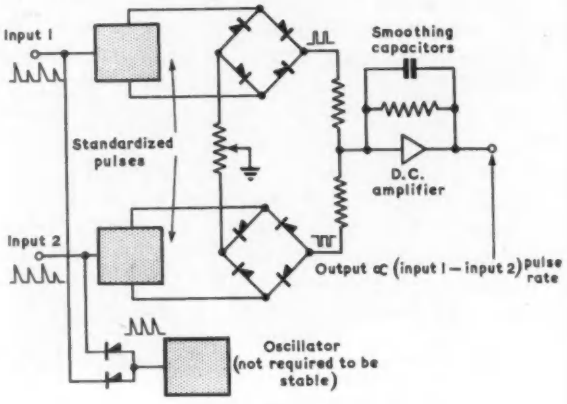


Fig. 5

$$P = \frac{\text{pulse duration}}{\text{inter-pulse interval}}$$

$$\text{i.e. } P_{\text{signal}} = \frac{\text{signal pulse length}}{\text{signal pulse interval}}$$

$$P_{\text{aux.}} = \frac{\text{aux. pulse length}}{\text{aux. pulse interval}}$$

the combined probability of two pulses occurring at the same time is $P_{\text{signal}} \times P_{\text{aux.}}$

An example may be helpful here. If the maximum signal pulse rate is 2500 pulse/s, i.e. repetition time = 400 μs and the pulse length is 50 μs,

$$P_{\text{signal}} = \frac{50}{400 - 50} = \frac{1}{7}$$

if auxiliary pulse rate = 250 pulse/s
i.e. repetition time = 4000 μs
and the pulse length = 50 μs

$$\text{then } P_{\text{aux.}} = \frac{50}{4000 - 50} = \frac{1}{79}$$

so that probability of pulse clashing is

$$P_{\text{signal}} \times P_{\text{aux.}} = \frac{1}{7 \times 79} = \frac{1}{553}$$

thus at max. signal input pulse clashing would only give a probable error of 1 in 550

At lower pulse frequencies P_{signal} becomes proportionately smaller so that the probable error decreases from this maximum figure. The auxiliary pulse-rate generator frequency is not required to be known to any degree of accuracy as long as the same auxiliary pulse signal is injected into each pulse-rate meter.

Processing sine-cosine into velocity information

Several linear measuring systems produce displacement signals primarily as two-phase sinusoidal information. Thus a crossed diffraction grating system currently in use produces such a signal from two sets of photocells, such signals being summarily squared before insertion into a suitable counter

In the method described elsewhere (*6*) the two sinusoidal signals are differentiated to enhance signal size, proportional to velocity. The two differentiated signals are then phase-demodulated with respect to the opposite initial signal. In this manner two trains of rectified sine waves are produced in such a relationship that they can be combined to reduce the ripple content of the signal, which is then an analogue of the input velocity.

The signal has approximately 30% ripple over the range and further smoothing is required to produce a useful signal. The ripple amplitude decays with output signal amplitude and its fundamental component frequency is four times the input frequency.

The success of this method depends to a large extent on the maintenance of a well-shaped sine-cosine input voltage of stable peak amplitude.

CONCLUSIONS

A number of methods for the detection and measurement of linearly derived velocities have been presented, and the table below lists the main features for ease of comparison.

TYPE	USABLE VELOCITY RANGE	UPPER VELOCITY LIMITATION	LOWER VELOCITY LIMITATION	LENGTH TO ACTIVE STROKE RATIO	NATURE OF UNWANTED SUPERIMPOSED SIGNALS	ORDER OF ACCURACY EXPECTED	DISADVANTAGES	ADVANTAGES
Homopolar generator with rack and pinion	*Depends on the effective pinion diameter*	*Disk flutter speed*	*Inherently low output voltage*	1	*Small. Slip ring noise only*	½–2%	*Very low output*	*Low noise*
D.C. tachogenerator with rack and pinion motion		*Safe mechanical speed*	*Disappearance of signal in commutator noise*	1	*Fairly large. Commutator noise*	½–2%	*Large ripple at lower voltage*	
'Induction' tachogenerator with rack and pinion motion		*Safe mechanical speed*	*Inherently low output voltage*	1	*Small—high frequency tooth ripple*	2%	*Stable input reference needed. Low output voltage*	*Low noise*
Capacitor tachometer with rack and pinion motion		*Minimum capacitor recharging time*	*Disappearance of signal into spurious noise*	1	*100% amplitude changes before smoothing*	1%	*High ripple*	*Low inertia*
Self-generating seismic mass velocity transducer	*Transient velocities only*	*Limited by maximum stroke of seismic mass*	*Amplifier noise level*	*Small unit abutting on to table*	*Cross-coupling from other axes*	5%	*Cross-coupling*	*Only a.c. coupled amplifier required*
Integrated output from seismic mass type accelerometers	*Suitable for transient velocity only*	*Max. acceleration or resonant frequency*	*Loss of output in spurious signal. Carrier signal stability*	*Small unit abutting on to table*	*Cross-coupling from other axes*	5%	*Can be expensive if cross-coupling to be avoided*	
Integrated output from self-generating piezo-electric accelerometers	*Suitable for transient velocity only*	*Max. specified acceleration for particular instrument*	*Amplifier noise level*	*Small unit abutting on to table*	*Cross-coupling from other axes*	5%	*Cross-coupling may be excessive*	*High self-resonant frequency. Not very expensive*
Standard pulse-rate-meter		*Resolution time and/or output saturation*	*Signal lost in large pulse noise*	*Length of grating slightly greater than length of stroke*	*Pulse charging ripple troublesome at low frequencies*	½–5%	*Failure at low pulse rates*	*Simple circuitry*
Pulse-rate meter with auxiliary pulse input		*Resolution time and/or output saturation*	*Depends on balance between rate-meter settings*	*Length of grating slightly greater than length of stroke*	*Small pulse charging ripple*	½–5%	*Extra auxiliary pulse equipment required*	*Continuous output through zero velocity*
Sine-cosine processing	*More suitable for transient velocity*	*Differentiator saturation*	*Signal failure due to a.c. coupling*	*Length of grating slightly greater than length of stroke*	*Approx. 30% noise before smoothing*	5%	*Cross-coupling may be excessive*	*High self-resonant frequency. Not very expensive*

Acknowledgment :
The work described has been carried out as part of a Machine Tool Development project at the Manchester College of Science and Technology, sponsored by The National Research Development Corporation.
The project is continuing under a grant from the Department of Scientific and Industrial Research.

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2. *Ibid*, p. 298
3. West, J. C.: *Servomechanisms* (E.U.P., 1953), p. 143
4. *Trace recording equipment and transducers used in the aircraft industry* (S.B.A.C. report)
5. Cooke-Yarborough, E. H., and Pulsford, E. W.: *Proc.I.E.E.*, 98 (Part ii).
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7. Johnson, C. C.: *Proc.I.R.E.*, 1952 (Feb.) p. 1911

PART 2

Modern control methods are most useful on the utilization side, but new techniques are creeping into manufacture and distribution as well

Getting over problems in the gas industry

by **R. E. CLIFFORD**
London Research Station, Gas Council

In Part 1 last month we explained how quality is specified in the gas industry. We then went on to describe some of the quality-control applications, and gave a brief account of three control systems that have been used to produce gas mixtures of any required aeration or Wobbe number.

Gas mixing

It is intended to use all these gas mixing systems in the control laboratory of the proposed new Gas Council laboratories, and the control arrangements include some novel features. The system is shown diagrammatically in Fig. 6.

To produce a gas of exactly 730 Wobbe number under all conditions a two-stage control system is necessary. A Sigma-Kent Wobbe controller will be used to increase the town-gas Wobbe number to 740 by adding propane when the incoming gas is at less than 740 Wobbe units, and a second Wobbe controller will be used to reduce the index from 740 or above to exactly 730 by adding air. This differs from normal practice, where control above and below a required control setting is usually achieved by means of a 'split range' system, that is by dividing the 3-15 lb/in² control signal into two sections, 3-9 and 9-15 lb/in². Each of these two sections operates a separate control valve through a 2-1 bias relay, which doubles the value of the control signal, so that each valve will operate throughout its whole range.

Separate controllers will be used for each operation in the system described above. This is to ensure absolutely steady control at the required Wobbe number, as even very small variations from this figure might upset tests on appliances. The total range of flow through the system will be between 2000 and 15,000 ft³/h and sudden large changes in demand may occur. These changes will tend to affect the controlled Wobbe number because of lags in the control system, and an additional flow-correction control is to be installed to prevent this occurring. A ring-balance flowmeter, operating on the differential pressure produced by an orifice plate in the main gas stream, will integrate, indicate and record the gas flow. A pneumatic control unit will be fitted in the flowmeter, and, in the event of sudden flow changes, the unit will modify the control signal transmitted by the two Wobbe controllers to their respective control valves. This modification will be effected by a diaphragm relay unit, known as a 'differential summator', placed in each of the lines between the controllers and their control valves. When a change in rate occurs this device will temporarily modify the signal from both the Wobbe controllers, and then, as the Wobbe instruments respond to the changed conditions, the flow correction signal will gradually fade out.

Part of the 730-Wobbe-number gas will be fed along four separate streams to four other control systems. Two of these will be cone-height controllers, preparing gas of any required aeration number continuously, and two will be Union Wobbe controllers, to be used for preparing air/gas or propane/gas mixtures of any required Wobbe number. A continuous feedback rate from each of these controllers to the inlet low-pressure main will enable them to tick over at times of no load, and will give more stable control when the demand is small.

Industrial applications of quality control

In some special industrial applications it is essential to have a flexible fuel of constant unit heat capacity, and town gas of a controlled Wobbe number is usually the best solution. This is particularly the case with

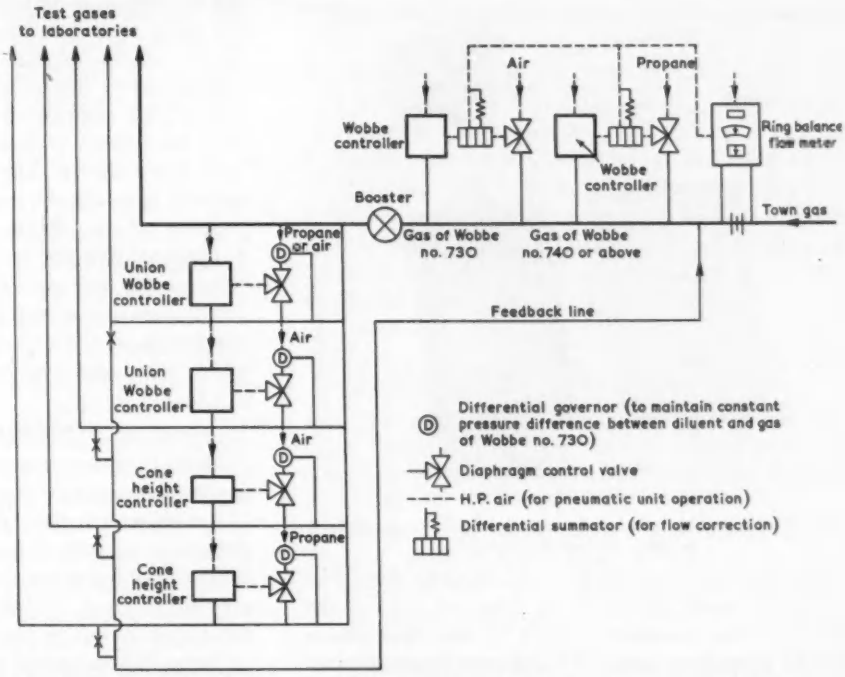


Fig. 6 Proposed layout in new Gas Council laboratories

those processes working on a timed cycle, as in the production of electric light bulbs. Variation of the heat input to the burners at any stage of the process may result in considerable wastage of material, and there may be a delay while the burners are readjusted (*5*), (*6*), (*7*). Installed at factories where very precise control of the heat input is required, Wobbe control systems usually improve efficiency considerably, and at the same time reduce the percentage of rejects.

There are various methods of installing such control systems, depending upon whether the gas is mixed with air in the required proportion on entering the factory, or at individual machines. In the former case, the mixed gas is fed to a Wobbe controller and the pneumatic unit alters a control valve and adds more or less town gas to the mixed gas before it is compressed, so that the Wobbe number of the mixed gas is maintained at a constant figure. When the air and gas are mixed at each individual machine, the district-gas Wobbe number is controlled to the lowest figure likely to be reached in the area. This is done by the addition of air to the gas before it reaches the machines.

Another interesting application of the Wobbe control system is in the preparation of controlled atmospheres to maintain the condition of some metal surfaces during heat treatment (*7*). For example, even a slightly oxidizing atmosphere will lead to the formation of red cuprous oxide during the annealing of copper, and hydrogen will also have a deleterious effect on the copper. The Wobbe controller can be used to maintain the air/gas ratio at the correct figure for complete combustion, so that there is no excess air to produce oxidization, and no excess gas, and therefore hydrogen, present. The mixture of most normal gases, with just sufficient air to ensure complete combustion, will have a Wobbe number of about ninety, and if the gas-air mixture before combustion is maintained at this figure by means of a Wobbe controller, the resultant atmosphere can be held within close limits, and very much better performance can be obtained than with hand regulation. This is not, of course, a direct means of control, but an inferential method of the open-loop type, as the presence of any harmful constituent in the controlled atmosphere will have no effect on the control system.

GAS-ANALYSIS CONTROL

Direct methods of combustion control for gas-fired furnaces form an interesting new field, and modern methods of gas analysis have made rapid and accurate control possible. These methods rely for their operation on the differing physical characteristics of the gases present after combustion. Thermal conductivity methods are used for carbon dioxide, sulphur dioxide and other gases; infra-red absorption techniques for carbon monoxide and carbon dioxide etc.; and a paramagnetic method is used for oxygen analysis.

The first of these methods of gas analysis relies upon the different thermal conductivity of various gases. If a heated wire is placed in a cooler gas it will lose heat by radiation, convection and conduction. Provided the first two of these effects are kept constant, the rate of heat loss will vary with the thermal conductivity of the gas surrounding the wire. If it is assumed that there is only one variable in the gas mixture, then the proportion of that variable can be ascertained by measuring the temperature of the wire. This is usually achieved in practice by making the wire one arm of a Wheatstone bridge and placing another wire in a sealed cell containing air. Any out-of-balance potential is measured by a recording potentiometer.

Fig. 7 Electronic relay unit and electrode for a flame-rectification control system

Infra-red analysis methods* are suitable for gases with absorption bands falling in the infra-red part of the spectrum. The radiation emitted by hot filaments is directed down two tubes, to a detector fitted with two windows. This unit is filled with the gas to be analysed, and is split into two equal cells by a diaphragm. These cells are affected by the radiation absorbed by the gas to be analysed. If one of the tubes between the radiant source and the detector is filled with a gas mixture containing a proportion of the appropriate gas, then part of the radiation will be absorbed, and this will affect the temperature and therefore the pressure in one cell. The diaphragm, which is made one plate of a condenser polarized through a high resistance, is deflected because of the change in pressure. A rotating shutter chops the radiation and the resultant pulsation of the diaphragm produces a proportional alternating current. This current is amplified, rectified, and indicated on a meter.

The paramagnetic method of oxygen analysis† is novel, and uses a property peculiar to oxygen amongst most common gases. It is attracted by the strongest part of a magnetic field, whereas most other gases tend to seek the weakest part of a magnetic field. In one form of oxygen analyser this attraction is used to produce a 'magnetic wind' which cools one platinum winding and heats another. The out-of-balance resistance created affects a Wheatstone bridge circuit, and the change in potential is recorded on a potentiometer.

All these types of analysis convert the response obtained into an electrical signal which is amplified and recorded with practically no instrument lag. It is then a simple procedure to use a standard control unit, operated by the movement of the recorder, to maintain the proportion of the gas analysed at any required figure.

One example of the practical application of the oxygen analyser is in the control of air to large furnaces (*8*). For many years combustion control systems have relied on the analysis of carbon dioxide in the products of combustion to control the amount of inlet air or fuel supply. The principle aim of such control is to minimize the amount of excess air in the flue gases so that heat is not wasted. The use of carbon dioxide recorders for assessing the amount of excess air in furnace products of combustion is an inferential method, and is likely to give rise to errors if the carbon-hydrogen ratio of the fuel gas varies, or if there is incomplete combustion. An accurate oxygen recorder gives a direct assessment of the amount of excess air present, provided there is no leakage of air into the flue.

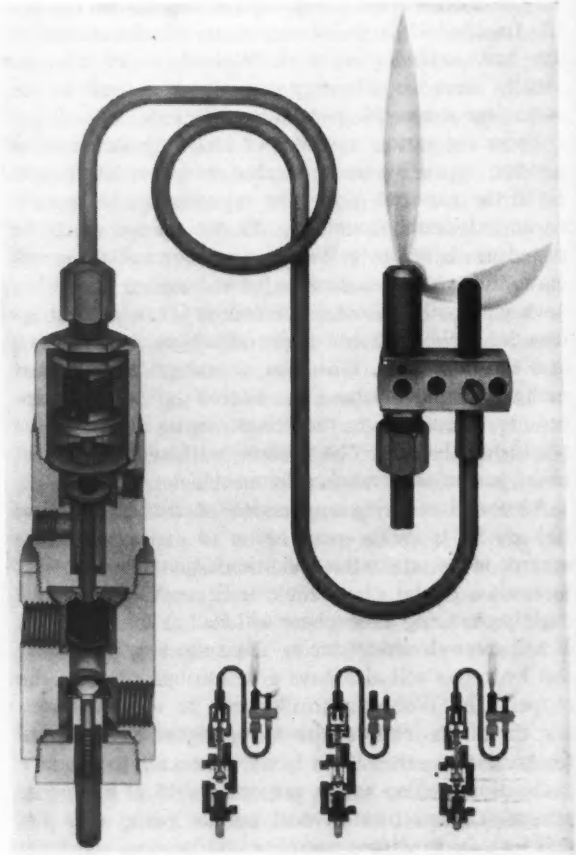
*See also page 108 of CONTROL for December 1959, and page 91 of this issue.—EDITOR

†See also page 129 of CONTROL for December 1959.—EDITOR

FLAME-FAILURE CONTROL

There is now a multitude of devices for controlling gas furnaces, central heating systems and many industrial appliances (*9*). The principal object of these devices is to prevent gas passing to the main burner until a pilot flame has been established, and also to cut off the gas supply if the pilot flame is extinguished. On the larger industrial gas appliances, electronic systems of flame-failure control are used, while the smaller industrial and domestic burners incorporate thermo-electric or thermal-expansion devices.

Fig. 8 Arrangement of a typical thermo-electric valve



The electronic systems used can be divided into two main categories. The first of these groups consists of equipment using the electrical conduction by a flame, and the second relies upon the detection of radiation from the flame.

Flame-conductivity systems

The presence of ions formed in the course of combustion renders a flame electrically conductive. A heat-resisting electrode carried in an insulated holder is placed so that it is in contact with the flame, and a small voltage is applied to the electrode. If a flame is present the circuit is completed, via an earthed burner, and if the resistance of the flame is within the range for which the circuit is designed, a relay is operated.

One difficulty with this type of device is that it is possible for foreign matter to fall across the electrode, creating a leakage path having a resistance within the operating range while there is no flame present. Recent devices working on the flame-conductivity principle have incorporated 'safe start' circuit modifications to eliminate this source of danger, and these are operated only by a moving or 'flickering' flame. An alternative type of flame-conductivity device uses the rectifying properties of a flame, and although this introduces slight technical difficulties in obtaining rectifying conditions, it is unlikely that foreign matter will simulate flame conditions.

Photo-electric sensing systems

These devices depend upon the detection of radiation from a flame and are sited to view the flame from a convenient position, thus avoiding contact with the flame or any particular hot part of the apparatus in which they are used. This has the advantage that expensive heat-resisting materials are not necessary. The main difficulty in the use of photoelectric systems is in differentiating between radiation from the flame and radiation from surrounding brickwork. A satisfactory solution is to use a flame-sensing system that is responsive only to the fluctuation in radiant intensity associated with all types of flame, that is, the 'flickering' effect.

Flame control applications

All these flame detecting systems provide a signal which is fed into an electronic circuit. This signal is amplified in the usual way and is used to operate relay switches which actuate solenoid valves, etc., to control the main gas supply. On the larger burner systems complex switching cycles can be initiated by the flame detection device. A typical fully automatic cycle as used on a direct-fired air heater would be as follows:

1. On turning on the electricity supply to the control system a fan starts, purging the combustion chamber with air. The fan operates a switch, actuated by air flow, which completes the circuit to the unit and energizes the electronic circuit. At the same time a motor-driven programme controller starts and the timed cam sequence allows the full operation to take place in the correct order.
2. After an adequate pre-purge period the pilot gas valve will be energized and the pilot flame ignited with a high tension spark.
3. If the pilot flame is detected as described above, then relays will be operated and the main gas valve will be energized (assuming, that is, that any thermostatically operated circuit is calling for gas), and the main burner flame will be ignited by the pilot.
4. Should the flame be extinguished, an electrically operated relay opens immediately shutting off the main gas only, and provides a high-tension spark at the pilot burner, which is still supplied with gas.
5. If the pilot flame is detected, the main gas valve re-opens, but if the pilot is not re-established in the time allowed, both pilot and main gas valve are closed.
6. The fan continues to run for a post-purge interval, after which it shuts down, and the unit remains in a state of lock-out until the manually operated re-set button is pressed.

Thermo-electric systems

Smaller appliances, using a simpler form of flame protection, usually rely upon the output from a thermocouple to hold a solenoid valve off its seating whilst the gas is alight. On failure of the flame, the thermocouple cools and a spring opposing the solenoid eventually closes the valve. An advantage of this system is that no independent electricity supply is required, but the lag in operation is high, usually over thirty seconds, and it is also necessary for all thermo-electric valves to be manually re-set.

OTHER METHODS

The majority of control applications described in this survey are concerned with the utilization side of the gas industry, because it is in this field that modern control methods are especially useful. However, the use of automatic control and instrumentation systems is rapidly increasing throughout the industry, and in the distribution section modern techniques of remote flow and pressure control are being widely employed. The manufacturing stations are also replacing, wherever possible, the traditional methods of manual control with automatic systems. Calorific value control of water gas dilution, automatic control of plant exhauster speed, control of oxygen addition to gas purifying plant, and dew-point control of gas humidity are all applications that have been attempted, and many such systems are now in constant use.

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End

PART 1

A few months ago, CONTROL readers saw a tussle over electric flying-controls. Here is a strong challenge to the opponents of electric engine-controls

Electric controls on the Britannia

by **GEORGE M. STURROCK, B.SC.(ENG.)**

Chief Development Engineer, Ultra Electric Ltd.

THE USE OF THE GAS TURBINE ENGINE IN MODERN AIRcraft has greatly increased the problems of designing suitable linkages for operating engine throttle valves. In addition to the general difficulties of contending with wing flexure, backlash, thermal expansion, ducting through pressure-tight partitions and freedom from frictional losses, greater accuracy of throttle positioning is being demanded. Furthermore, in the case of some modern turbo-prop engines, the linkage is required to operate not only the throttle valve but also a propeller control mechanism which exerts considerable and reversible torque.

Whilst the designers of mechanical linkages are faced with these formidable problems, the electric throttles of the Britannia aircraft have now logged about a million hours of flight experience. It may therefore be of interest at this juncture to consider the record of this equipment, to detail briefly the functions which it performs and the philosophy pursued in making it as safe and reliable as it has proved itself to be.

The electric throttles of the Britannia do not only replace ordinary mechanical linkages. They also govern engine accelerations and speed in flight and provide protection for the turbine blades against over-temperature. By carrying out these extra functions they replace certain units of the hydraulic fuel systems in addition to the mechanical throttle-linkage.

Development of the electric throttle

The electric throttle of the Britannia started life as a control system for very large aircraft of the Bristol Brabazon and Saunders-Roe Princess variety some twelve years ago. The main reason for adopting an electrical system was the difficulty of designing an accurate-enough mechanical linkage to operate the engine throttles of aircraft of this size. At the same time the engine manufacturer was demanding more accurate control of both engine-speed and jet-pipe temperature, and there was the further problem of preventing compressor surging when the engine was accelerated.

The original equipment was a simple electronic speed-governing system, the datum of which could be varied continuously by the pilot. This electronic speed-governor functioned quite satisfactorily over the working power range of the engine, and accuracies of the order of 0·1% were attained with stable operation.

Despite the fact that no actual failures of electronic valves occurred during these tests, the idea of valve equipment having 100% control of an engine was viewed with some concern. Failure statistics of electronic valves were not encouraging, and although much was being said about the development of a range of so-called 'ruggedized' valves, it was plain that this would be a long-term project. From the United States, where development was more energetically pursued because of the greater demand, reports were filtering through of disappointing results. It was therefore decided at this stage that instead of valves the more reliable, but in some ways less meritorious, magnetic amplifier would be used for the amplification of control signals. The main disadvantages of magnetic amplifiers were their comparative novelty in Great Britain and their relatively long time-constants. On the other hand, they were said to be as reliable as a transformer, and they required no warming-up period before operating, being in fact operative from the moment of switching on.

In order to overcome the difficulties of speed governing at low engine speeds, it was decided to alter the basic conception of control. An extensive examination of the requirements was made and a proposal put forward which was finally agreed and accepted. The final agreed form of the electric throttle is as follows:

1. It is basically a remote throttle-positioning system in which the engine throttle is automatically brought into angular alignment with the pilot's control lever. The accuracy of alignment achieved is of the order of ¼°. This is roughly equivalent to a mechanical linkage in which there exists ¼° backlash. Its advantage over a mechanical linkage, apart from its freedom from backlash, is that no unwanted throttle movements take place owing to wing flexure or expansion of the linkage with change in temperature, and so on.

2. Speed governing is now incorporated as a trim function selectable at the pilot's discretion. This operates on the engine throttle by feeding into the basic positioner a signal which deliberately misaligns the engine throttle in relation to the pilot's control lever. A maximum of 20° closure of the engine throttle in relation to pilot's

control lever is allowed.

3. Temperature control is incorporated, and acts, like the governor, by feeding a throttle-closing signal into the basic positioner. In the event of the temperature rising above a predetermined datum, the action of the temperature control is automatic and overrides the speed-governor if this is in control.

4. Engine accelerations are also controlled in accordance with engine temperature. In this case control is effected by governing the speed at which the engine throttle is allowed to follow up the movements of the pilot's control lever. Although the pilot may move his lever from idling to full power as rapidly as possible, the engine throttle will open at a speed such that the engine temperature is maintained to a schedule during the acceleration. Such accelerations possess advantages over an air/fuel-ratio-controlled acceleration. For instance, in the air/fuel ratio control, compressor delivery pressure (modified or unmodified) is used as a measure of air flow. In the event of surging having taken place, compressor delivery pressure no longer represents air flow, and the air/fuel ratio control is unable to take the engine out of surge. In the case of temperature-controlled accelerations, even the onset of surging is accompanied by a rapid increase of temperature which, acting through the temperature channel, is usually in itself sufficient to prevent the surge even in the incipient stage. Should the surge develop, however, the temperature remains high and the action of the control continues until the engine is automatically taken out of the surge condition.

Safety features

The philosophy of safety on which the electric throttle was designed assumes that failures of the equipment will at some time occur, and that in the event of such failure all reasonable precautions shall have been taken without having had recourse to duplication or triplication of the circuitry.

As a first necessity it was decided to incorporate an emergency control system so that, in the event of any failure whatsoever of the main control, the pilot would still be able to open or close the engine throttle as required. This emergency control has been made as simple as possible and operates from the 24 V d.c. battery supply whereas the main control operates from the 115 V 400 c/s supply. It was also considered desirable to prevent the main system from driving the throttle either fully open or closed in the event of any failure. Ideally the throttle should remain in the position that it occupied prior to any failure, but in view of all the possible types of failure which might occur, this is extremely difficult to ensure in all cases. Statistically it was shown that the majority of failures in aircraft equipment are caused by open or short circuiting of the interconnecting cables and plugs between units of the whole equipment, and the safety system finally incorporated gives the necessary protection against such failures. The system is also protected against many internal faults, since the external cabling is a continuation of internal circuits. The safety system was also required to operate if the power supply showed excessive variations of voltage and frequency, since this could cause malfunctioning of the temperature channel as well as being indicative of a faulty inverter. The presence of a failure is indicated by a red warning light.

Such a safety circuit is, in itself, almost an installation tester, since it checks that all interconnexions are properly made. This aspect has, in fact, proved to be the most useful.

The following paragraphs describe briefly and simply how the electric throttle is built up and how it operates. Fig. 1 illustrates diagramatically the basic positioning system.

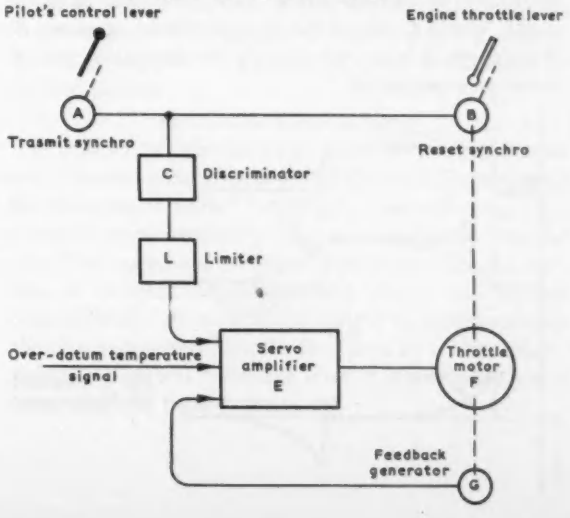
Basic positioner control

This is based on simple servo principles and incorporates pancake synchros and a.c. servo motors in conjunction with magnetic amplifiers.

The transmit synchro *A* is coupled directly with the pilot's control lever, and a feedback synchro *B* is directly coupled with the engine throttle valve. Any angular misalignment between *A* and *B* gives rise to an alternating-current position-error signal which is converted to a d.c. error-signal by a discriminator *C*. The maximum value of this d.c. error-signal (in the opening sense) is limited by the limiter *D* and is then fed to the servo-amplifier *E*. The servo-amplifier operates the throttle motor *F* which moves the engine throttle valve and the feedback synchro *B* through suitable gearing. This is the usual form of electrical follow-up servo and the system comes to rest when the error signal has been reduced to zero, i.e. when *B* is in alignment with *A*. The feedback generator *G* driven by the throttle motor *F* develops a d.c. voltage proportional to the speed of the latter, and this signal is fed to the input of the amplifier *E*. This makes the throttle motor speed exactly proportional to the magnitude of the position-error signal fed to the amplifier.

Fig. 2 shows the characteristics of the basic positioning system in terms of throttle-actuating speed against position-error signal. The actuating speeds are impor-

Fig. 1 Basic positioning system



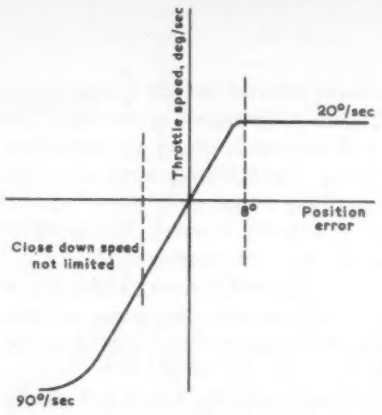


Fig. 2 Speed:error characteristics of positioning system

tant, as will be realized when engine acceleration aspects are considered.

In the positive (or opening) direction of the throttle, the limiter *D* makes equal all error signals the magnitude of which correspond with a position error of more than 8°. In this way the engine throttle opening speed is limited to a maximum speed of 20° per second.

In the negative (or closing) direction, no limitation is introduced, and when the pilot's control lever is 'shut down' rapidly, the engine throttle follows at a rate of 90° per second.

For small throttle movements the maximum speeds are not reached.

Temperature-controlled accelerations

The greatest problem is the large delay exhibited by the jet-pipe or turbine-entry thermocouple in following a change. This is aggravated at low engine speeds and high altitudes since it depends on the mass flow of gases past the couple. Time delays of the order of 1·6 to 2 seconds exist. Fig. 3 shows how this delay is overcome.

Curve *A* represents actual gas temperature and shows the condition where there is a step change of temperature from a value θ_1 to a higher value θ_2 and a return to value θ_1 after some interval of time.

Curve *B* shows the thermocouple signal in response to the step change. The signal rises exponentially, finally settling to the new value corresponding with the temperature θ_2. It then dies down again exponentially when the gas temperature returns to θ_1. The delay in response is clearly seen. It is relatively simple to obtain a first derivative or rate-of-change term from an electrical signal. Curve *C* shows the first derivative of curve *B*. Since curve *B* is an exponential, the derivative curve *C* is also an exponential.

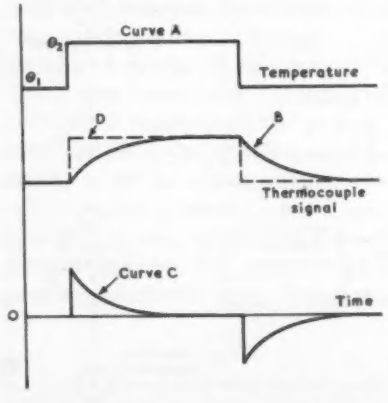


Fig. 3 Response of thermocouple

It will be seen that if curve *C* is added to curve *B*, the resultant curve *D* is of exactly the same form as the curve *A*. In other words, if the rate of change of the thermocouple signal, suitably amplified, is added to the thermocouple signal, a resultant signal is obtained which is a measure of the gas temperature without any time delay being involved.

In practice, curve *B* is not quite an ideal exponential, there being some aberration at the beginning of the temperature change, but it is possible to obtain an effective reduction of the thermocouple time-delay by a factor of about ten. Thus a fairly rapid signal-response is obtained from thermocouples which possess a relatively long time-constant.

Fig. 4 shows the overall form of the temperature channel used for controlling accelerations. Block *A* represents the circuitry for reducing thermocouple delay, discussed above, so that a signal is obtained from *A* which is more or less an instantaneous measure of gas

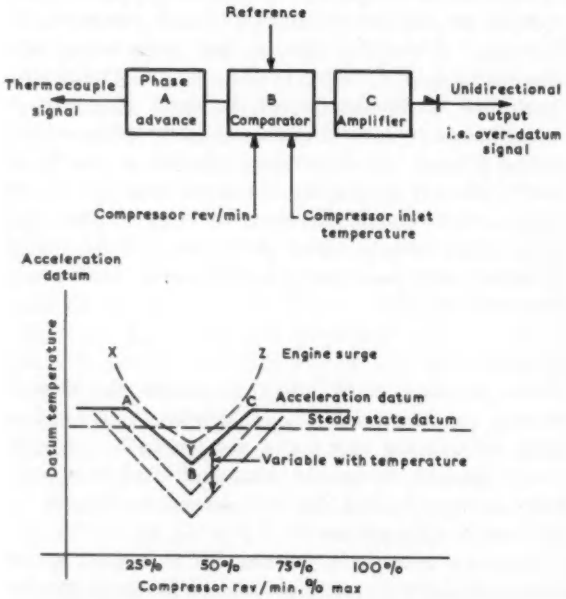


Fig. 4 Temperature channel for acceleration control

temperature. For servo-control this signal must be compared with the command or datum at which the servo is designed to regulate the gas temperature. This operation is carried out in block *B*. In the case of accelerations the required datum is not a constant temperature but depends upon the instantaneous value of compressor speed and the temperature at the compressor inlet. Block *B* is therefore more than a comparator; it is also a datum computer and is fed with the necessary speed and compressor-inlet-temperature signals to perform the computation. Below the schematic diagram of the channel, the required datum curve is illustrated. It shows a depression in datum over a certain speed range to avoid the surge zone of the engine. The shape of the depression is subject to the existing compressor inlet temperature.

To be continued

PART 2

Practical applications to the control of gas mixture, combustion efficiency, inert-gas generation, solvent recovery and moisture

Process control with infra-red gas-analysers

by **A. E. MARTIN, D.SC., A. M. REID, A.M.BRIT.I.R.E.** *and* **J. SMART**
Sir Howard Grubb, Parsons & Co. Ltd.

In Part 1, published last month, we described the principle of operation of the infa-red gas-analyser. After discussing sampling problems we went on to consider the analyser as an element in a control loop.

Theory

Much has been written on theoretical aspects of control and this topic can only be touched on briefly here. (See for example Young (*3*)). Let us suppose that the problem is to adjust operating conditions continuously so as to maintain the output of the infra-red gas-analyser (which may be a current or pressure, p_m) as nearly equal as possible to a desired value, p_d. Any difference between p_m and p_d may be regarded as an error signal θ. The output current from the analyser when applied to an electro-pneumatic converter provides a pneumatic signal with which a valve or other control element may be operated in such a manner as to reduce θ to an acceptably small value or even to zero.

The simplest control system is on/off and might be applied, for example, to tunnel ventilation, the requirement being to switch on ventilating fans when the concentration of carbon monoxide reaches a prescribed level. More refined control is provided by a proportional controller which applies control action proportional to the error signal. Thus a large amount of carbon monoxide would cause the fans to run at full speed whereas a small amount would require them to run at low speed or fewer fans to operate. The 'proportional band' is defined as the percentage of full scale on the measuring instrument which brings into action full control. Thus if full scale corresponds to 0·05% carbon monoxide and this invokes maximum ventilation, the proportional band would be said to be 100%.

Fig. 5 indicates the possible course of events following a sudden disturbance to the operating conditions in a chemical plant. In the absence of corrective action the error signal θ would change to θ_1 but we will suppose that a controller is provided to reduce θ to an acceptable level. The manner in which θ is corrected will depend on the characteristics of the control system and in many cases the correction curve will be similar to one of the alternatives shown. *AB* represents dead time during which there is no indication of any change in the operating conditions and therefore no corrective action can be taken. To make the best use of the first signs of change derivative control is employed, but even this may not be rapid enough to prevent dangerous conditions from being set up in the plant, and other overriding controls operating on temperature or pressure at danger points must be provided.

Different plants may have very different requirements. A large and complex chemical plant will have numerous time lags and operational changes will normally occur quite slowly. The principles of control will follow well-established lines and extremely good control should be possible in most cases.

On a solvent recovery plant, however, the requirements are quite different and a relatively simple control system is adequate. This type of plant is discussed in the next section.

PRACTICAL APPLICATIONS

In many cases the use of an infra-red gas-analyser as an automatic controller is straightforward. Reverting to the example of tunnel ventilation, since the large fans normally used inevitably take a considerable time to reach full speed and to slow down again when the current is switched off, the control system will present little difficulty. As soon as the carbon monoxide reaches the chosen concentration the fans start up automatically, reduce the carbon monoxide level to a prescribed lower limit, and are then switched off.

Mixture of gases

A more difficult control problem is that of mixing two gases A and B and maintaining the proportions constant. In Fig. 6, A and B are conveyed by separate pipe lines which finally meet to give mixed gas in a single pipe. It will be supposed that the flow of A is liable to vary and the flow of B must be varied by a controller in order to keep the concentration of A in the mixture constant. Either one or two analysers may be used. If one only is employed the concentration of A is measured directly while if two are used to measure A and B separately, the ratio will be automatically in-

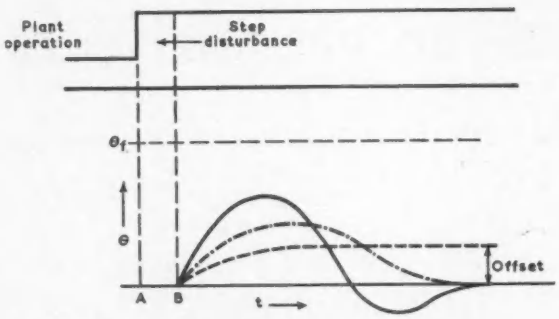


Fig. 5 Action of controller in typical system

dicated and any departure from normal used to actuate the controller which in turn varies the opening of valve V.

Suppose that an error signal θ from the analyser or ratiometer requires an angular change of $C_1\theta$ in the position of valve V in order to reduce θ to zero and that the valve is driven by a d.c. motor, suitably geared down, from the amplified error signal so that an angular change of $C_1\theta$ in the valve position corresponds to an angular change of $C_2\theta$ in the motor armature position, C_1 and C_2 being constants. When the step change occurs, producing an instantaneous error θ, a torque of $C_3\theta$ acts on the motor armature, C_3 also being a constant, and the equation of motion is

$$C_2 J \frac{d^2\theta}{dt^2} + C_3\theta = 0$$

where J is the effective moment of inertia of the armature and associated moving parts. The form of this equation indicates that the valve will oscillate sinusoidally about the mean position and in order to obtain a steady value it is necessary to introduce a damping signal which may conveniently be obtained by attaching a tachometer generator to the motor so that a d.c. voltage proportional to the angular velocity of the motor shaft is produced. This voltage is subtracted from the amplified error voltage so that the driving torque is reduced by $-C_4\frac{d\theta}{dt}$, where C_4 is a constant. The equation of motion now becomes

$$C_2 J \frac{d^2\theta}{dt^2} + C_4\frac{d\theta}{dt} + C_3\theta = 0$$

and by choosing a suitable value for C_4, the system may be damped to any desired degree.

Combustion efficiency

The maintenance of maximum efficiency in many types of combustion equipment is of great economic importance since enormous quantities of various fuels are consumed in this manner. With large air-to-fuel ratios the carbon dioxide is diluted and a comparatively low carbon dioxide concentration found; but as the air supply is reduced the carbon dioxide rises steadily until a maximum is reached and thereafter the dioxide is progressively replaced by monoxide, which therefore increases while dioxide diminishes to a low value. At large air-to-fuel ratios energy is wasted in heating useless air while at low ratios unburnt carbon monoxide represents a loss of energy.

It is clearly impracticable to control combustion conditions by means of the carbon dioxide content since a given concentration corresponds to two different air/fuel ratios. One possible method of control is to make use of the fact that in the neighbourhood of the carbon dioxide maximum a small amount of monoxide exists and its concentration is very sensitive to the air/fuel ratio. It is possible therefore to choose a small monoxide concentration, say 0·5%, and control at this level. One drawback to this procedure is that if at any time the air supply should be increased substantially the monoxide will drop to zero and control will be poor.

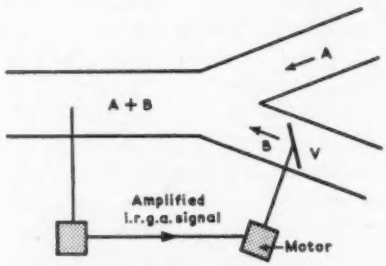


Fig. 6 Controlled mixing of two gas streams

An alternative method of control (patent applied for) is to use an infra-red gas-analyser sensitive to both monoxide and dioxide, the relative sensitivity being adjusted so that

$$[CO] + k\,[CO_2]$$

as indicated by the output signal (k being a constant), rises steadily as the air/fuel ratio is reduced.

Inert gas generation

In many industries an adequate supply of gas to provide an inert atmosphere is essential and several manufacturers provide suitable gas generators which depend on the controlled combustion of a readily obtained fuel such as town's gas, fuel oil, propane, etc. (Fig. 7). The products of combustion comprise mainly carbon dioxide, nitrogen and water vapour together with small quantities of one or more of the following: oxygen,

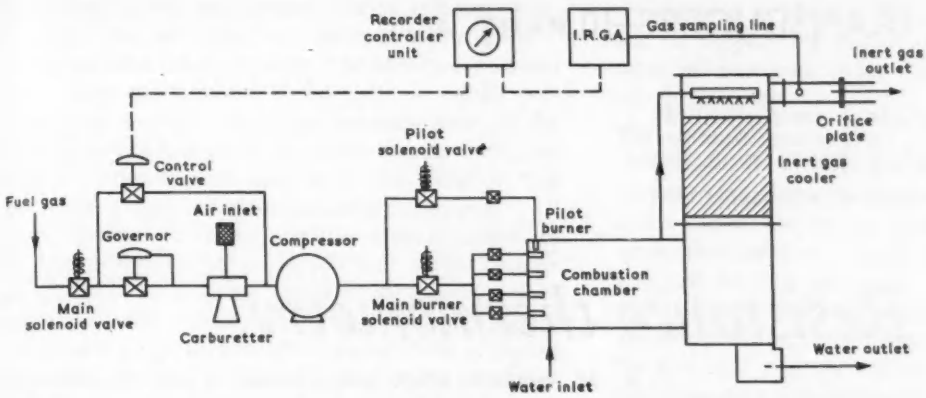


Fig. 7 Inert gas generator

hydrogen and carbon monoxide. In some cases carbon monoxide must be completely absent while for other purposes oxygen must be eliminated. Water vapour is readily removed by condensation and adsorption drying, while carbon dioxide and other acidic gases such as sulphur dioxide may be removed, if desired, by monoethanolamine solution, which has the advantage as an absorbent that it can be regenerated when necessary by applying heat and driving off the carbon dioxide. Reasonably pure nitrogen can be produced quite cheaply in this manner.

Quality control is applied with an infra-red gas-analyser by monitoring carbon monoxide in the combustion gas. Fortunately, high sensitivity to this gas is obtainable (full scale for 0·05% by volume) and all that is necessary is to control the air/fuel ratio to maintain a constant low level of carbon monoxide. Alternatively, if carbon monoxide is to be completely absent, a small pilot combustion may be controlled to give a small carbon monoxide content, while the main combustion is carried out with an air/fuel ratio increased in a fixed ratio with respect to the pilot combustion.*

Solvent recovery

Every year, by use of active carbon in specially designed plants, many millions of gallons of solvent used in various industrial processes are recovered from the atmosphere and used again. Two types of plant have been developed for this purpose; one is static and discontinuous while the other is capable of continuous operation. In each case an infra-red gas-analyser can be used to control the operation of the plant.

In the static plant one or more adsorbers charged with active carbon are used to extract solvent from the air stream until the carbon approaches saturation. When this condition is reached the air supply is either shut off altogether or diverted to fresh units, while steam is fed into the saturated units to drive off the solvent vapour which can subsequently be condensed and separated from the accompanying water. By having several adsorbers and staggering their operation, virtually continuous operation can be achieved. The function of the infra-red gas-analyser is to determine when each adsorber reaches saturation by monitoring the air leaving the unit, break-through of solvent indicating that the adsorber is ready for steaming. Automatic operation of valves can readily be provided so that fresh units are brought into action as required, while saturated units are steamed out for a pre-determined time so as to be ready for use in their turn.

The continuous recovery plant employs a single bed of active carbon which rotates slowly and continuously. While a large part of the adsorber is being charged with solvent, steam is passed through another section, already saturated, in order to drive off the solvent. Up to a certain throughput no control action is required but for large installations where several units may be installed, in order to obtain economical operation additional units can be switched on and off according to the load. The total quantity of solvent passing into the plant in unit time is obtained by multiplying together the air flow and concentration of solvent; and the minimum number of units necessary to deal with this quantity of solvent are automatically put into operation. In this case the infra-red gas-analyser is used rather differently since the solvent concentration is measured before the air stream enters the adsorber.

For either type of plant it is the function of the controller, acting on information supplied by the infra-red gas-analyser, to switch units in or out as may be necessary, a reasonable time lag being introduced to prevent unnecessary switching. Such control depends mainly on the ingenious use of relays and timers and more elaborate control devices would be out of place.

Moisture control

As a final example, the moisture content of process air is frequently important, e.g. processes involving paper, and rapid control of humidity is essential. An infra-red gas-analyser can be used to monitor water concentration and by controlling a water spray maintain relative humidity at any desired level, provided that air temperature is also maintained constant.

*Our thanks are due to Messrs. W. C. Holmes & Co. Ltd. for information regarding inert gas generators.

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End

ELECTRICAL TRANSDUCERS—10 PART A

An account of the latest developments as well as established practice in this branch of temperature measurement

Resistance thermometry

by **K. M. GREENLAND, B.SC., PH.D., F.INST.P., F.R.M.S.**
British Scientific Instrument Research Association

RESISTANCE THERMOMETRY IS BASED ON THE CHANGE IN resistance of an electrical conductor with temperature. The temperature coefficient of resistance of a suitable metal can be very stable and reproducible, and resistance values at different temperatures can be compared with great accuracy. These two facts give the resistance thermometer its superiority over other thermometers in the range − 200°C to 1200°C. It holds a high position as an industrial thermometer because, in addition to its accuracy, reproducibility and excellent stability, it is very sensitive, easily coupled to standard indicators, recorders and controllers, and readily adjusted to cover narrow or wide temperature intervals.

Among the metals which have a high temperature coefficient, platinum gives the most stable and reproducible resistance element. In its most refined form the platinum resistance thermometer is in fact specified for the determination of temperatures on the International Temperature Scale between the boiling point of liquid oxygen and 630°C. Platinum is chosen not only for precision thermometry but also for the majority of industrial resistance thermometers. The only other metal which is used to any considerable extent is nickel. This is cheaper, so that a more robust gauge of wire can be used, and it has a temperature coefficient 50% higher than that of platinum, giving an even higher sensitivity. The upper limit of its working range is set by the Curie point at 360°C. The other disadvantages of nickel are that its temperature coefficient of resistance cannot be controlled as closely as can that of platinum, and the relationship between temperature and resistance is far from linear, whereas that of platinum is nearly linear.

In recent years the commercial production of the *thermistor* (' thermally-sensitive resistor '—a semiconductor having a very high negative temperature coefficient of resistance) has been developed to a point at which the stability of a thermistor resistance thermometer can generally be relied upon to within 0·1°C per annum. Thermistor elements are particularly useful for the direct operation of relays in temperature control.

Those advantages of the platinum resistance thermometer which are due to the purity and stability of the metal are shared with noble-metal thermocouples; what, then, determines the choice between resistance thermometer and thermocouple for a particular application? The salient feature of the resistance thermometer is that it is very much more sensitive to a change in temperature than is a platinum/platinum-rhodium thermocouple. Even the more sensitive low-temperature noble-metal thermocouples and the base-metal thermocouples do not give a signal as large as that from a platinum resistance thermometer in its appropriate resistance bridge circuit. A 10°C scale range is possible with the resistance thermometer and an additional advantage is that by a simple adjustment of the bridge resistances the temperature interval chosen for the full scale range may be placed anywhere within the working limits of the thermometer. An incidental advantage of the large signal from the element itself is that the thermal e.m.f.s do not cause trouble and there is, of course, no cold junction temperature to be controlled or compensated.

Since the measuring circuit for a resistance thermometer can be an a.c. bridge the output signal is ready for electronic amplification without the intervention of the d.c.–a.c. converter (the vibrator or ' chopper ') which must be used with a thermocouple. Alternatively it is possible to use a d.c. bridge with either a chopper and electronic recorder or an electromechanical (galvanometer) recorder. Sufficient power can be controlled by a resistance thermometer—d.c. bridge combination to actuate a moving-coil relay without any amplification of the thermometer output.

CONSTRUCTION OF A RESISTANCE THERMOMETER

Resistance thermometers may be divided into two classes, the precision type and the industrial type. (This does not imply that the industrial type is of low accuracy—on the contrary, the emphasis which has already been laid on the superior accuracy of resistance thermometers is justified by the performance of the industrial type.) Differences in the method of construction between these two classes are due on the one hand to the necessity of avoiding any possibility of strain in the resistance wire for the highest precision, and on the

other hand to the requirement that an industrial thermometer shall withstand the hazards of industrial use—vibration and mechanical shock. The internal connexions also differ; the precision thermometer is usually provided with separate current and potential leads for the potentiometric method of resistance measurement; the industrial thermometer may have two, three or four leads and a resistor for standardizing the output.

A thermometer of the precision class is capable of measuring temperature to 1/1000°C. It would be used in national and industrial standardizing laboratories, in apparatus such as bomb calorimeters, and in analytical procedures based on accurate determinations of boiling or freezing points. In industrial applications the accuracy of measurement is generally about ± ½%; it is determined rather by the meter or control unit than by the thermometer itself, but with more refined control apparatus limits of ± 1° at 1200°C are maintainable.

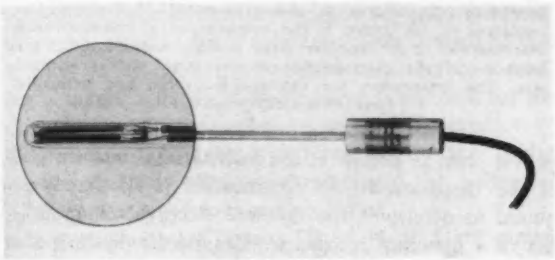


Fig. 1 Precision resistance thermometer made by H. Tinsley & Co.

The precision thermometer

The design illustrated in Fig. 1 may be taken as an example of a commercially produced precision thermometer; it is based on the work of C. R. Barber of the National Physical Laboratory. The platinum resistance element consists of two formerless helical coils loosely supported in thin-walled glass tubes. Two short thick platinum leads are attached to each end of the coil and are pinched in the upper ends of the glass tubes. Outside the pinch a gold lead is welded to each platinum lead and these four leads are carried in two twin-bore silica sheaths. The elements and leads are protected by an outer glass sheath which carries at the 'cold' end a connecting head for the four-core connecting cable, thermally insulated to ensure that thermal e.m.f.s at the junctions are exactly balanced. The sheath is gas-tight and is filled with dry helium.

The four-lead construction makes it possible to use this thermometer either with a potentiometer or with a Smith or Mueller bridge. In the potentiometric method a steady current is passed through the thermometer coils by means of one pair of leads and the p.d. across the coils alone is measured by connecting the other pair of leads to a potentiometer. This p.d. is compared with that across a standard resistance in series with the thermometer coils; The ratio of the two voltages is then equal to that of the two resistances. The Smith and Mueller bridges are refinements of the Wheatstone bridge. They are designed to eliminate the effect of lead resistances and to simplify the procedure of accurate measurement. All four leads of the thermometer are connected into the bridge.

The industrial thermometer

In resistance thermometers intended for reliable service and long life under industrial conditions the design which ensures for the resistance element a completely strain-free condition is abandoned for one which gives a rugged structure and quite a small size of thermometer. The coil is always wound on a former. For high accuracy this may be of two crossed mica strips with the wire held in notches in the edges of the strips; for fast response a flat element is formed by winding the wire on a single mica strip; for durability, however, the favoured construction consists of a cylindrical ceramic former carrying the resistance helix, which is coated, after winding, with a glaze to protect it and hold it firmly in place. Anodized aluminium is sometimes used instead of ceramic, to reduce strain due to differential expansions. The thermometer coil with its own leads (and sometimes one or two extra leads for temperature compensation) are protected by a sheath which is usually of alumina or steel. It may be filled with air or hydrogen.

A great variety of sheath dimensions is available: the sheaths are normally 6 in. or more in length and ¼ in. or more in outside diameter. Improvements in the technique of construction are making it possible to reduce the diameter and length of the thermometer coil and to strengthen it against vibration. For very special purposes thermometers in sheaths with an outside diameter of ½ mm have been made. A series of industrial resistance thermometers is illustrated in Fig. 2.

When the greater accuracy conferred by platinum is not required, nickel is able to offer the advantages of cheapness, robustness and a 50% greater sensitivity. For surface temperature measurements in the range − 50°C to 150°C, resistance elements of ·001 in. diameter nickel wire are made in the form of a flat grid and embedded in Bakelite on a Bakelite-impregnated backing film. These are cemented to the surface under test.

One of the outstanding features of platinum resistance thermometers is the reproducibility of their resistance-temperature relationship. It is therefore possible to supply factory-adjusted thermometers which are truly interchangeable. The length of wire in the thermometer coil is first adjusted to give a standard increase of resistance when the temperature rises from 0°C to 100°C and a manganin or minalpha ballast resistance is then added to bring the ice-point resistance to a standard value. This ballast resistance is built into the head of the thermometer.

Speed of response

Although the construction of a resistance thermometer gives it a higher heat capacity that that of a thermocouple the time constant is determined as much by the

sheath as by the sensing element. Figure 3 demonstrates the effect of sheathing a fast resistance thermometer.

CALIBRATION AND CHOICE OF FUNDAMENTAL INTERVAL

The resistance R_t of a platinum resistance thermometer at temperature t ($t > 0°C$) is related to the resistance R_0 at 0°C by the relationship.

$$R_t = R_0(1 + at + bt^2)$$

For $t < 0°C$ the relationship is more nearly

$$R_t = R_0[1 + at + bt^2 + c(t - 100)t^3]$$

In very accurate work the constants a, b, and c are determined by measurements at the ice point and the boiling points of oxygen, water and sulphur*. For less exacting applications the bridge circuit associated with the indicator or recorder is adjusted to balance point with a standard resistor representing the thermometer, and the scale, marked in °C or °F, is printed to a predetermined scale form. The thermometer with its ballast resistance already built-in will then give an indication correct to, say, 0·5%. An alternative method of adjustment applicable to cam-driven pen recorders is to adjust the cam. Individual pointing of the instrument scale is resorted to when greater accuracy is demanded.

The range of resistance variation for a given temperature range is determined by the value of $(R_{100}-R_0)$ where R_{100} is the resistance at 100°C. The magnitude of this term is known as the *fundamental interval* (f.i.) of the thermometer; its specification is all that is required to determine the nominal electrical characteristics of a platinum resistance thermometer, since it also defines R_0 with fair accuracy. This is due to the fact that the ratio R_{100}/R_0 is very sensitive to impurities in the platinum, and only wire having a minimum value of 1·390 in the strain-free condition is (or should be) used. A value of 1·3923 is achieved commercially. As the maximum value attainable is 1·3925, the value is closely controlled. Thus, the fundamental interval is nearly equal to 0·4 R_0.

The fundamental interval may be chosen to suit the characteristics of a standard indicator or recorder, the higher values being suitable for the shorter ranges, but in the case of installations with long uncompensated leads it is necessary to have a thermometer coil of high resistance (and hence a large fundamental interval) in order that variations of lead resistance with temperature shall not be significant. Normal f.i. values range from four to ten ohms (R_0 from 10 ohms to 25 ohms) with 25 ohms to 30 ohms as a high value. A coil of ten ohms f.i., a value favoured for precision measurements, requires two metres of 0·1 mm diameter wire. *Nickel* resistance thermometers are made with fundamental intervals up to thirty ohms.

MEASURING CIRCUITS

The simplest way of detecting changes in the resistance of the thermometer is to apply a constant e.m.f. and to measure the current in the circuit. As the variable component of the current to be measured is small compared with the steady component, this is not a sensitive method and is not much used in normal practice. A modified Wheatstone bridge circuit (shown in its

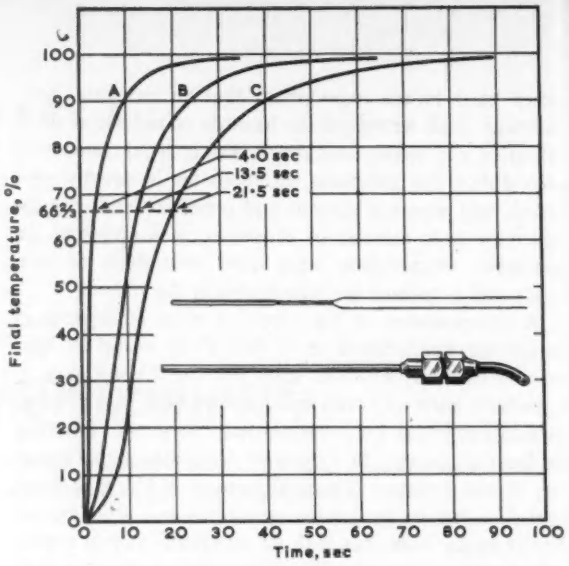
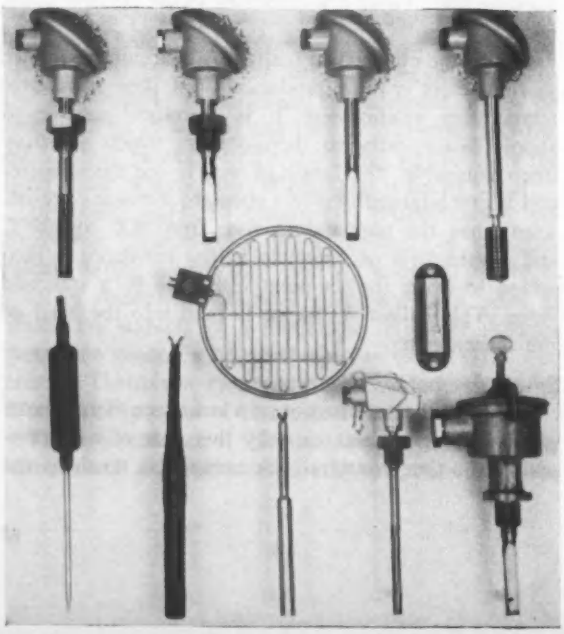


Fig. 3 Special fast-response resistance element by the Foster Instrument Co. Curve A shows response of thermometer immersed in oil, curve B the response of a wax-embedded thermometer in a stainless steel pocket, and curve C the response of the thermometer in the same pocket without wax. The instrument has double-silk-covered and varnished formerless nickel windings

* In British Standard 1904-1952 (Commercial Platinum Resistance Thermometer Elements) are given the values of these constants which may be assumed for thermometers constructed in accordance with the Standard.

Fig. 2 Industrial resistance thermometers produced by the Cambridge Instrument Co.

In the top row, left to right, are : 1—Mica former enclosed in flat metal sheath. Sensitive bulb held in position by flat spring. Intended for screwing into steam pipes and places where there is considerable vibration. 2—Standard steatite bulb for same uses as 1, but not under vibration. 3—For flange mounting in flues, steam pockets, etc. 4—Quick-response instrumen: for fluid temperatures up to 120°C. In the bottom row, left to right, are : 1—Special notched mica former in metal sheath, for melt temperatures. 2—Standard steatite bulb in vulcanized rubber, mainly for ships' holds. 3—Standard steatite bulb, hermetically sealed, for use in soil. 4—Small steatite bulb for sub-zero temperatures. 5—Standard steatite bulb assembly with weatherproof terminal head, for outdoor use. Middle row, left to right : 1—Bifilar loop of silk-covered wire in brass capillary wound in ring; designed for blanket temperature-measurement, but also used for gas ducts etc. 2—Small steatite bulb mounted perpendicularly for quick-response measurement of air temperature in cold stores etc.



simplest form in Fig. 4) is favoured for industrial measurements, but a more refined bridge or potentiometer is required for precise work.

The precise methods have already been briefly described, so attention will now be given exclusively to methods suitable for industrial thermometry.

There are two ways of operating the Wheatstone bridge: one (the *deflexion* method) is to hold the three bridge resistances constant and to indicate or record on a galvanometer scale (graduated directly in degrees) the off-balance current, which is a measure of the resistance and hence temperature of the thermometer; the other method is to adjust one of the bridge resistances, or to vary the ratio of two of them, to maintain balance of the bridge. In the latter method (the *null-point* method) the position of the slider of the variable resistance is indicated on a scale graduated in degrees.

In the deflexion method, the deflexion of the galvanometer depends on the bridge voltage, so this must either be supplied by a constant-voltage source or else it must be adjusted to a standard value before a reading is taken, a fixed resistance being substituted for the thermometer. In the null-point method the position of the slider for balance is independent of the bridge voltage; the only effect of variations in this voltage is to affect sensitivity to a minor degree.

Both methods are catered for in the standard ranges of industrial indicators, recorders, and controllers. The null-point method is now commonly operated by self-balancing electronic servo-amplifiers and in this case the bridge is usually a.c. operated.

The bridge current is chosen to match the sensitivity of the measuring transducer (deflexion or null-point), but a maximum is set by the self-heating characteristics of the thermometer. Normal bridge currents are between 20 mA and 50 mA and with such comparatively low currents the error due to self-heating is negligible.

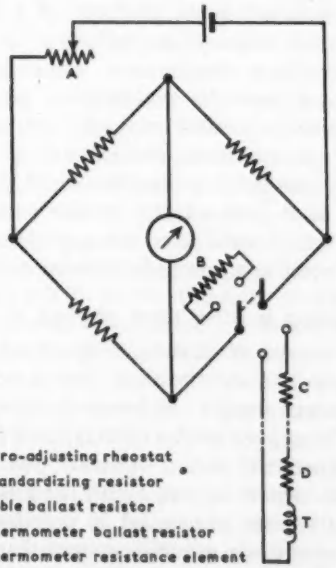


Fig. 4 Wheatstone bridge for resistance thermometer

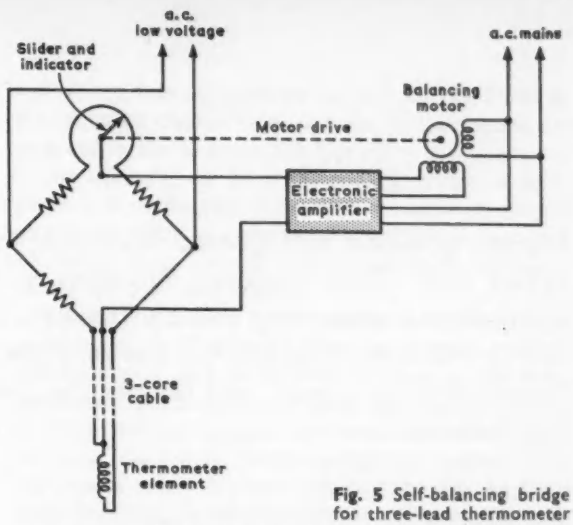


Fig. 5 Self-balancing bridge for three-lead thermometer

The simple Wheatstone bridge circuit (Fig. 4) is quite adequate for measurements of moderate accuracy, but variations of the resistance of the connecting cable with temperature contribute an error to the indicated temperature. The *two-lead* thermometer used here should therefore be of high resistance. Since only moderate accuracy is expected with the two-lead system the deflexion method is normally used for indication. A current of 100 μA is a typical value for full-scale deflexion, and this current can be indicated by a galvanometer designed to operate satisfactorily in industrial environments.

The two-lead system is convenient for multi-point installations as the switching is simple, but although temperature differences in the leads will not bring in serious errors, different lengths of lead could cause zero errors; it is therefore necessary to add cable ballast resistances adjusted for each run of cable to equalize the total resistance of each circuit.

When greater accuracy is called for than can be given by the two-lead system, and especially when cable runs of several hundred feet have to be provided, a bridge circuit is employed in which the resistance of the cable does not affect the balance-point of the bridge. To match this improvement, it is usual to operate on the null-point method in order to eliminate bridge voltage variations entirely. The circuit for a *three-lead* thermometer with electronic amplifier and self-balancing bridge is shown in Fig. 5. It will be seen that the two current-bearing leads to the thermometer are connected in adjacent arms of the bridge and a third lead, the resistance of which does not affect the balance of the bridge, connects the thermometer coil to the detecting unit. Provided, therefore, that the resistances of the two current leads remain equal they do not affect the null-point setting. This combination of three-lead thermometer and self-balancing bridge will give an accuracy of about 0·5°C and a reproducibility of about 0·2°C for a scale range of 100°C at any temperature up to 500°C.

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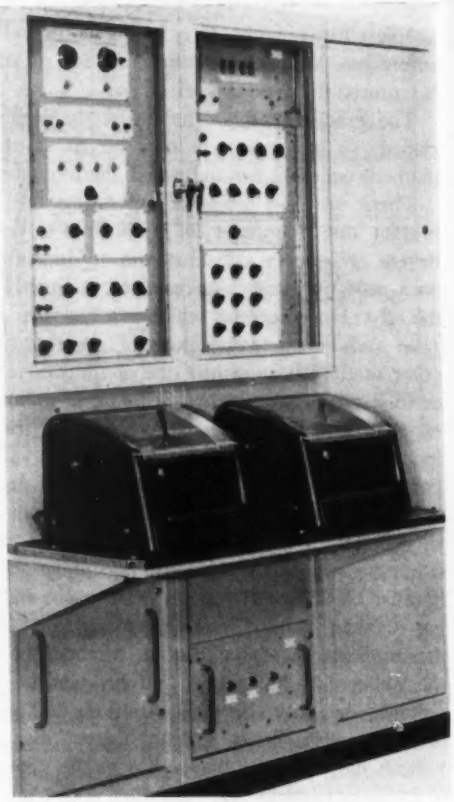
To be continued

The Measurement and Control Section of the I.E.E. talked over 'Data Handling Problems in Atomic Installations' when they met on Tuesday, December 15. Here the opening speaker enlarges on the remarks that he made, and reports the discussion that followed

Handling nuclear data

by **DENIS TAYLOR, M.SC., PH.D., M.I.E.E.**
Director, Plessey Nucleonics Co. Ltd.



B.S.D. data processing system for the C.E.G.B. station at Berkeley

DATA HANDLING SYSTEMS ARE BEING USED ON AN increasing scale in chemical plants and other industrial installations. Data handling is now beginning to make an impact on nuclear energy installations, particularly in the case of nuclear reactor plants.

Although the control of present types of gas-cooled nuclear-reactor plant can be regarded as inherently simple, many measurements apart from those of the neutrons in the reactor core are necessary for safe and efficient operation. For example, it is important to check the flow, pressure and temperature of the coolant as it passes through the core. Fuel elements and moderator temperatures must be measured to ensure that they do not rise above the highest permissible working temperature. Provision must be made for detecting any escape of radio-active products so that steps can be taken to avoid contaminating the coolant circuit. Other instruments are needed to measure the amount of radiation at various locations around the plant. The result is a great complexity of instruments and large quantities of information which have to be logged or recorded.

Present developments involve the provision of data-handling systems to observe the measurements made by all the many instruments, and call the attention of the control engineer to any abnormality in the readings. An additional facility is also provided, when necessary, for checking the sequence of events leading to such abnormality. This calls for the provision of some memory system. It is not usually necessary to look back very many hours, so the provision of a data-handling system with a memory can result in a simplification of the whole system. Furthermore, when something goes wrong and a particular instrument or group of instruments indicates a value markedly different from the standard value, or varies its indication at a rate different from normal, it is possible to call the operator's attention to the abnormality so that corrective action can be taken. In some cases, it is appropriate, of course, for the corrective action to be initiated automatically.

Data handling at other types of plant

The provision of data-handling systems at nuclear installations is a definite trend, but it not limited to nuclear power stations. Elaborate data-processing systems are being proposed for other types of plant, notably isotope separation plants. Generally, two different requirements have to be met. Firstly, data handling (and, if necessary, data processing) is provided at nuclear plants to ensure safe and efficient operation of the plant; and secondly, data processing is provided for statistical

investigation of the causes of abnormalities, etc. Both are equally important at this stage because of our usually incomplete knowledge; but as time goes on, and our experience is extended, and reactor types become more standardized, the first will obviously assume the major importance.

Data handling at nuclear reactor plants

Although data-processing systems have been installed on a number of power reactors for some specific purpose, the complete system as envisaged in my opening

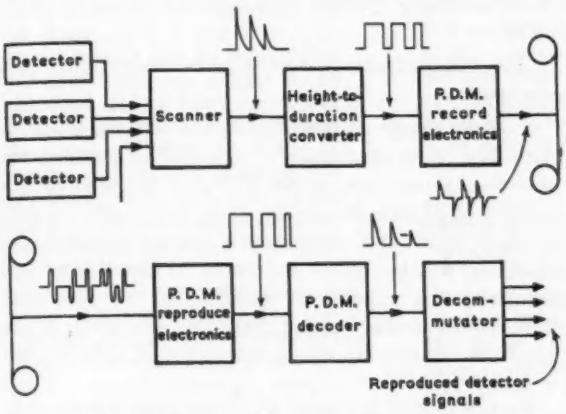


Fig. 1 Pulse duration modulation equipment

remarks is still a long way off. However, complete data-handling systems have been evolved for nuclear power tests, automatic data-reduction replacing hand logging and plotting. Fast accurate systems of this type have been constructed to gather the transient and steady-state data needed for the design of efficient and safe nuclear power plants in the future.

Examples of this type of system are available in the literature. Thus, Edwards (*1*) has described a nuclear power test-loop in which the quantities monitored, of the order of a thousand input variables, are passed as electrical signals to a programming patch panel, and then passed to a recording and monitoring panel, a scram monitor, a slow data-reducer, and a fast data-reducer feeding into a digital computer.

In the case of actual nuclear power stations, data-handling/data-processing systems have been used so far with only limited objectives. Thus Sunvic Controls (*2*) are building a data-processing system for the burst-slug detection system at the C.E.G.B. nuclear power station at Berkeley. They employ a system in which the parameter corresponding to the fission-product activity for each channel is counted in a scaling circuit, and is passed as a binary count to a digital computer which stores the information. For most of the time the activity figures are normal and are not of immediate interest, but if any abnormality arises the control engineer is immediately alerted by an alarm, and the computer, with its memory facility, makes it possible to examine the sequence of events leading to the abnormality, as well as continuously printing out the activity levels in the suspected channel from then on. In this system the print-out facility is an electric typewriter.

The advantage of the data-handling system as compared with the logging of the data on miniature graphs on pen recorders is a considerable increase in precision of measurement as well as a considerable saving in recording paper and labour.

Another application is in handling the thermocouple temperature data obtained from the several hundred thermocouples used in the core of each of the large gas-cooled power reactors being constructed in this country. Various systems are being proposed, some involving the use of rotary mechanical switches, mercury wiped relays or photoconductive crystals for high-speed switching to allow the thermocouple outputs to be measured and observed. In one system the outputs are presented on a c.r.t. The system is required to operate alarms if a particular thermocouple output moves outside a specified range and with the facility as before of being able to examine the sequence of events leading to the abnormality, as well as monitoring the suspected part of the core continuously following the abnormality. As in the previous case, some memory system is necessary, and apart from measuring the absolute temperature, it may be desirable to monitor the rate of change of temperature with time.

Magnetic tape is sometimes used in data-handling systems for nuclear reactor plants. Halfhill (*3*) has recently described how magnetic-tape techniques can be used to multiply the effectiveness of nuclear instrumentation by adding data logging, reducing and analysing capability. Some of the techniques used are illustrated in Figs. 1 and 2.

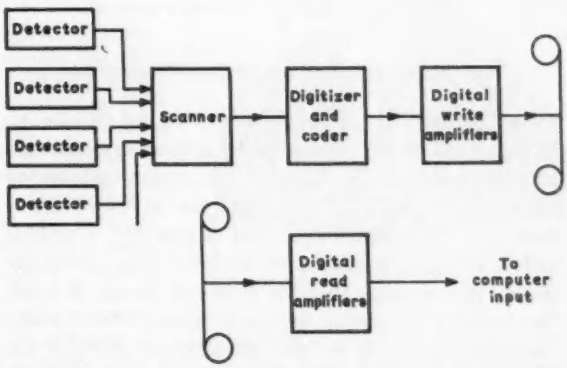


Fig. 2 Digital recording

Discussion at the I.E.E.

At the Institution of Electrical Engineers on December 15, a crowded hall demonstrated the interest and enthusiasm raised by the subject. There was discussion over a wide range of problems. Churchill of Sunvic Controls Ltd. gave a detailed statement on the methods which he had adopted in connexion with the design

of the b.s.d. data-processing system for Berkeley, and mentioned that the purpose of the equipment was to compare the measured variable with some maximum permitted level. He pointed out that as the measured variable was subject to statistical variations there was a probability of the alarm operating occasionally without a fault in a fuel element occurring, and he discussed this in terms of what he called a typical kind of burst. Clearly, by taking account of the previous history of the suspected fuel element channel it is possible to increase the probability that an alarm corresponds to a genuine fuel-element failure, and Churchill pointed out a number of ways in which this could be done.

E. H. Cooke-Yarborough (A.E.R.E.) spoke about the problems of data logging in nuclear physics experiments. He referred to the large amounts of data required for typical experiments and the long times for which expensive machines, e.g. multi-channel pulse-amplitude analysers, would be locked up if the measurements were made directly, and the considerable advantages which could be obtained by adopting a different approach to the experiment. He did this by referring to the measurement of the gamma-ray spectrum of neutron capture in platinum. His apparatus is shown schematically in Fig. 3. The data are stored in binary form on a magnetic tape, and afterwards examined with a suitable multi-channel analyser. One advantage of this procedure is that the tape can be run through the analyser at much increased speed, thus saving 'machine' time. It is also possible to increase the 'detail' of the information by running the tape through the analyser a number of times, the machine being so set up on each occasion to examine a different part of the spectrum.

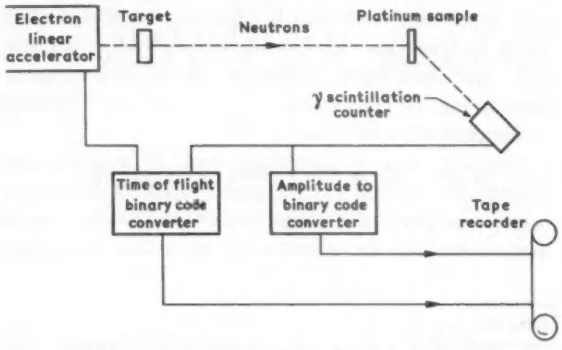


Fig. 3 Apparatus described by Cooke-Yarborough

Cooke-Yarborough's contribution created a great deal of interest, because apart from the use of the technique for nuclear physics experiments, it has also much potential use in reactor experiments.

Golder (U.K.A.E.A. Industrial Group) said that the Industrial Group had a different outlook from that of the Research Establishment on the operation of data processing equipment. They wanted equipment which would operate every hour of every day for 365¼ days of every year. Hence a very high standard of reliability was essential. He went on to discuss how this might be attained. He suggested that electromechanical devices might be avoided with advantage, but later in the discussion it was pointed out that to replace a Post Office selector switch with a transistor circuit might involve as many as 400 transistors and so one must conclude that the selector switch was a very useful component. In discussing data processing systems Golder suggested the following broad categories:

1. simple scanning systems with alarm facilities and identification,

2. data logging systems with print-out and alarm facilities,

3. complete systems with a large amount of data processing.

J. Roth spoke at length about processing temperature data in nuclear reactors, and McHaffer raised the question of whether we were wrong to set ourselves limited objectives (as we are doing at present) of processing b.s.d. and temperature measurements only. Would it not be better, he asked, to install universal machines now capable of handling all the measured data from a nuclear reactor plant? He also spoke of the need for simplifying the presentation of data to the operator.

Trotter (C.E.G.B.) spoke about the economics of data processing and tried to analyse the man-power requirements of a power station operating with conventional recorders as compared with one using data processing facilities. He took into account that the latter would involve more maintenance. No definite conclusion was reached as a result of this part of the discussion, but it was obvious that the problem will need to be resolved, as will also the question of determining the other advantages gained from a data processing system, before policy can be decided. Trotter suggested that the use of data processing might:

1. allow the plant to be operated at greater efficiency, i.e. allow the fuel elements to be run at higher temperatures,

2. provide increased safety to the plant,

3. allow better economics in operating the plant.

It was obviously important to settle these issues as soon as sufficient experience had been gained.

At the conclusion of the meeting there was much discussion about the high reliability obtained with data loggers in industrial (non-nuclear) plants, particularly in America, and estimates were made of the capitalized value of an operator as compared with the capital cost of data loggers. No definite conclusion was reached, except perhaps that high reliability was possible with these systems.

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Pick-off

by *'UNCONTROLLED'*

AN American electronics man called on me recently, on his way from England to Germany. He said that he was hunting for good European designs to be produced and marketed by his firm in the States. This rather surprised me, because I would have thought that there was enough designing and developing talent over there. Time seems to be the thing, however, and it looks more profitable to use production know-how on existing designs than to develop new ones.

My visitor saw little future for consultants in work on systems, but thought that there was a good market for manufacturers of components which users could fit themselves. Especially where fractional gains in efficiency make substantial differences to the economics of plant (as in the petrochemical industry), he considered that commercial security would decide control users against admitting 'systems experts' from outside. However trustworthy the consultant, the knowledge he gains on one project may find its way elsewhere and save a rival some of the cost of development.

This sort of argument has a speciously reasonable ring to my ear. Why stop at control-system components? By the same sort of logic, firms should develop all their own instruments. The ultimate conclusion is that no business can feel safe unless it integrates right down to the raw materials and keeps all staff for life. In practice, of course, the line is drawn at different places according to the needs of different users. There is perhaps a broader market available than my American visitor was prepared to admit, and I suggest that our precious few of consultants need not fear too gravely for their future.

THE Editor tells me of an interesting enquiry that he received from the instrument department of a New Zealand firm. Apparently the first news of the S.I.T. came 'down under' last September, in CONTROL's leading article. This suggests to me that the S.I.T. should consider broadening more horizons than those mentioned in our leader. I look forward to seeing details of Commonwealth branches in an early S.I.T. programme!

TOGETHER with a number of old boys and other friends of Cranfield, I enjoyed a dinner-by-candlelight at the College about a week before Christmas. The guests were introduced to the students on the fourth guided-missiles course, and an interesting assortment of nationalities there was to meet. The biggest contingent was Dutch, with half-a-dozen members. Then there were five Swedes, four Germans, three Indians, three Norwegians, two Yugoslavs, and one each from Belgium, Denmark and Italy.

The after-dinner speeches were particularly good, but with that exasperating kind of success that defies reporting. I cannot hope to sketch briefly enough the high spirits of the occasion, but I can mention some of the factual remarks. For example, I was interested to hear that thought is being given to the possibility of a one-year's course on 'space' technology. Indeed, from what I heard and saw, it is plain that diversification in the aircraft industry is being matched in Cranfield's planning. The first definite move is the establishment of an advanced school of automobile engineering, and this is due to start operations next October. One of the speakers asserted that, although the College is not near to any one centre of the automobile industry, it is on the centroid, so contentment should be properly distributed. This new component part will mark a step toward the growth of the College into a larger group of advanced schools.

CONTROL's leader last March advocated a National Control School, and put forward Cranfield as a candidate for this. I think that the College is now even better equipped for such a function—and the need is greater than ever.

NOBODY has yet produced an earlier example of an electrohydraulic servo than Westinghouse's governor of 75 years ago, which I mentioned in *Pick-off* a few months ago (CONTROL, Sept. 1959, page 118). Instead I have received another challenge, this time on data transmission. I am told that in 1875 one Marcel Deprez, a French electrical engineer, found himself with the problem of repeating a rotary motion at a distance. His method was to put a pair of two-segment commutators on to his transmitter shaft. These sent battery current alternately through two pairs of leads to a remote receiver. My correspondent writes that Deprez's

. . . a synchronous tie

technique clearly anticipates by many years the data-transmission devices known in H.M. ships as 'M-type motors'. Although the Frenchman used the minimum number of poles, fractions of a revolution were registered because the transmitter was moved through step-up gearing, and there was an equivalent reduction between the motor and indicator. In his description the inventor said that the system could work at 2000 rev/min without the two units falling out of step. It was, he remarked, 'as if one had joined them by a rigid shaft'; in other words, a synchronous tie.

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

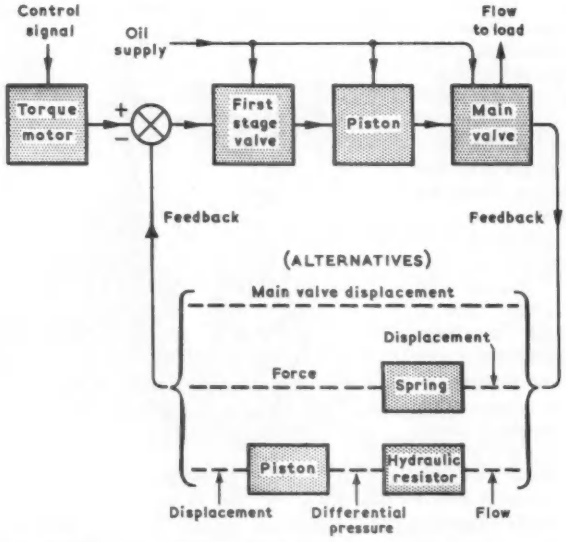
IDEAS APPLIED . . .

. . . to SERVOS

An introduction to hydraulic servo valves—4

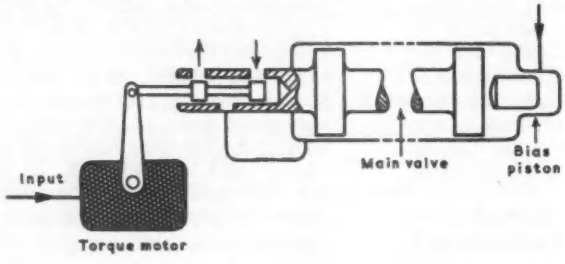
R. HADEKEL, Engineering Consultant, Sperry Gyroscope Co. Ltd.

This series of articles is addressed to engineers who are conversant with servo techniques in general, and who wish to acquire specialized information on hydraulic servo techniques. The first part dealt with one of the keys to these techniques—the servo valve. The second part gave the basic types of valves and their characteristics. The loads on slide-valves and the types of two-stage valves were discussed in the third part. Here some closed-loop arrangements are shown.

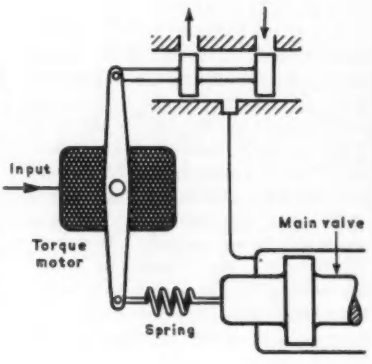


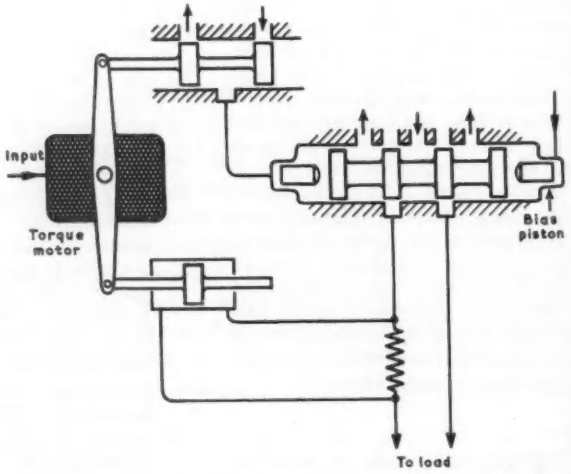
Closed-loop arrangements are characterized by very low sensitivity to loads on the second-stage valve, as the inner loop is made very stiff. Gain sensitivity to supply pressure is lower than with open-loop type. A diagram of possible feedback loops is given above.

An example of displacement feedback is shown below. This requires a relatively high torque-motor output, since first-stage travel is equal to main valve travel.



An example of force feedback is given in the diagram to the right. The first-stage travel is relatively very small. Hence the force signal is nearly proportional to main valve travel, and the effect is similar to that of displacement feedback, but torque-motor output is much lower. Action depends on load sensitivity of torque-motor.





Flow feedback, shown above, is relatively rare. Flow is strictly proportional to torque-motor output, and insensitive to supply pressure or load.

End

. . . to AIMING ERROR

Miniature camera

A midget camera, no larger than a cotton reel, has been designed for mounting in guided missiles to record target interceptions. It weighs 8 oz., has a diameter of 1½ in. and is 1¼ in. long.

The camera takes only one shot and is intended primarily for the measurement of missile attitude in relation to its target. A wide-angle lens gives a field of view of 186°, and the camera is usually triggered from a proximity fuze. The exposure time is 0·3 ms, and it uses Ilford film in the form of 0·93 in. dia. disks punched from 35 mm films. The electric triggering fuze requires 40 μJ for fully reliable firing, at a typical voltage of 150 V.

Miss distance can be measured to an accuracy of 5% and missile-to-target attitude, derived in conjunction with a wing-tip camera system, to an

Reel-ly small !

accuracy of approximately ± 1°. In terms of ground axes, attitude may be measured to an accuracy of ± 1° in pitch and roll, and, by reference to the sun, to ± 3° in heading. Accuracy of heading measurement may be improved by the use of ground features.

The camera was designed and developed by W.R.E. at Woomera, and is manufactured by Fairey Aviation Co. of Australasia Pty. Ltd.

. . . to FLOW RATE

Ultrasonic flowmeter

A flowmeter developed by B.S.I.R.A. operates by comparing the phase of ultrasonic signals transmitted with and against the direction of flow between a pair of transducers mounted in the pipe wall. Signals are normally propagated in liquids at speeds of the order of 1500 m/s; a signal travelling with the flow will make the transit more rapidly, while one travelling against the flow will be retarded slightly. By comparing the transit times through phase measurement of signals being propagated in the two directions, the velocity of flow may be determined.

One of the advantages of using a phase-comparison system is that accuracy of measurement is independent of speed of propagation through the liquid.

. . . to WAVE GENERATION

Optical-mechanical system

A function generator made by Advance Components produces any required function at any frequency between 0·01 and 100 c/s. This method of waveform generation differs from conventional oscillators in that an optical-mechanical system is employed. A narrow slit of light is scanned by a rotating disk on which is impressed an opaque area corresponding to the function to be produced, a phototransistor being used as detector.

The rotating disks (which are driven by a servo-controlled motor via a 4-speed gearbox to achieve frequency accuracy and stability) are readily interchangeable. The system offers great flexibility to the user, as it is only necessary to plot a function in polar co-ordinates for it to be available in varying-voltage form.

. . to LEVEL CONTROL

Pneumatic Proximity-probe

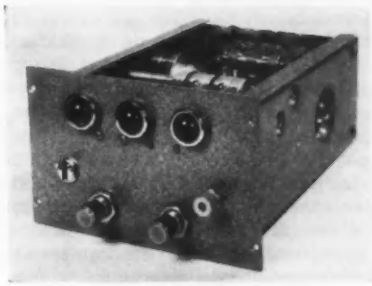
The novel bunker level-indicator of the Coal Research Establishment is a proximity-probe device working on low-pressure air, as distinct from electrical proximity-indicators. It is designed to indicate levels of material such as coal contained in conventional bunkers. The principle employed is that a low-pressure, low-flow air-current in a relatively large tube (2 in.) may easily be diverted to another channel incorporating an indicating device when the tube opening is obstructed.

The diversion is effected by a simple injector, fitted with a butterfly valve, which is included in the delivery line. The valve is closed until the back-pressure balances the induction pressure at the intake of the injector. Any obstruction at the end of the detector tube, which follows the injector, disturbs this balance, and the air supply is to some extent diverted through the normal injector intake. The intake aperture is fitted with a flap which moves upwards when the air is diverted as described above, and this movement closes a switch in the indicator circuit.

. . . to GAUGING

Building blocks

Building-blocks are employed often enough in electrical work but their use in pneumatic equipment is more rare. One of the most important uses for pneumatics in production engineering is in pneumatic gauging. The usual practice is to allow dimensions to fall within a given tolerance band, any deviation from this causing an alarm to be set off, indicating whether the component is above or below the tolerance allowed. In a large installation, up to sixty dimensions may be



Readily interchangeable

measured automatically in this way. This means that for each dimension the tolerance band must be carefully set up and calibrated at intervals, and this calibration, together with any alterations in the installation that may be required, demands a certain flexibility which is lacking in most pneumatic circuitry.

A different approach has been adopted in the latest of the gauging units made by Teddington Industrial Equipment Ltd. The pneumatic-electric relays required to set up the tolerance band are within the unit, and the calibration is carried out by operating the toggle valve, which then connects the unit to a central size-indicator. The lights on the panel indicate the band in which the component lies, i.e. over, correct or under size. Thus once electrical and pneumatic supplies, and a gauging head, have been connected to the unit, it is ready for setting up.

Given last month in an R.Ae.S. Branch lecture by S. R. Glaze, these general observations make an epitome of the . . .

Philosophy of an aircraft servo engineer

ON DECEMBER 3, 1959, A LECTURE ENtitled 'Some Servomechanisms in Supersonic Aircraft' was delivered by S. G. Glaze, B.Sc.,* to the Gloucester and Cheltenham Branch of the Royal Aeronautical Society.

The lecturer made a number of interesting general observations, and some extracts from these are reproduced below.

Beginning of design

From the initial recognition of the need to control a parameter, the task of designing a suitable system begins. Customarily, feasibility and/or design studies are undertaken on more than one method of achieving the desired objective. Once a point is reached at which a block diagram of the system proposed can be drawn, it is often possible to say with some certainty whether or not stable, accurate and fast operation will be obtained by suitable design effort. This is unfortunately only true for sizes, equipment and environmental conditions within experience. Future supersonic flight at least is not, in this sense, within experience. Absence and expense of test facilities in the extended ranges demand accuracy in initial theoretical explorations. Accuracy and wide environmental investigation of, for example, pneumatic servomechanisms mean a great deal of hard work with a very complex mathematics. Computational aids are invaluable, and, of those available, none is more suitable than the non-linear electronic analogue computer. An important point about such an approach is the relative ease with which variations on a basic theme can be investigated. The value of such enquiries, like most theoretical work, is incalculable.

Analytical synthesis

The modern trend is to write books on control system synthesis, but the point must soon be accepted by the readers that this synthesis is largely an analytical process. Economic and other factors generally demand that a new control system consist of components which existed before the system concept, and other components designed to fit in. The suitability of fit is ascertained by analysis of the implications of inclusion of suitable equipment. In short it is a trial and error procedure. This is a very powerful method of course, as nature has demonstrated. Nature has, however, taken a very long time to achieve its results.

A large number of trials is often essential to ensure success. The most powerful mathematical tool in analysis of dynamic systems is undoubtedly linearization, but in order to obtain even imperfect knowledge of a system in this way it may be necessary to perform several analytical essays, none of which is necessarily short nor especially informative. All practical systems are, unfortunately, non-linear. Some of the best known and well tried servomechanisms are highly non-linear; the Watt governor, the electric bell and the hydraulic jack are particular examples of this truth. Nothing is more certain than that the inventors of these excellent non-linear devices had no understanding of the detail with which a servomechanism engineer of to-day would go into their mathematics before including them in his system. There is evidently a moral here; and one of the clues to this is time allowed on the increasing complexity of systems.

Bringing in the non-linearities

To sum up, the approach of linearization is mathematically possible but difficult in a complex system, and of limited usefulness. There has been in the past a tendency to demand linearity in components for reasons such as, firstly, that there is no satisfactory way of (analytically) using a non-linear component; secondly, that the non-linear apparatus is more difficult to control; and thirdly, that there is a lack of interchangeability of non-linear components. Non-linear dynamical systems benefit only from a very limited mathematics, and what there is of it is very laborious and quite a special-purpose tool.

By making an analogue of a proposed system which accurately includes the non-linear aspects of a problem, the opportunity to gain time is achieved. Just as the great engineers of the past could cut and try again until they succeeded, so can the engineer of to-day, with the aid of an analogue computer, but at a pace more in keeping with the times. This is not a sufficient approach, of course. A great deal of common sense must be compounded with a thorough understanding of linear theory in order to get results. An empirical approach must be cultivated. It is an unfortunate fact that the true value of non-linear equipment has been, so far as we can judge by results to date, underestimated by most manufacturers of electronic analogues. It is difficult and expensive to manufacture this equipment to the necessary degree of accuracy, which is of the order of a true $\pm$ 0·1% or better. One would have thought the fact that this is the only method of tackling non-linear problems of this nature was sufficient guarantee of a market. In a non-linear system where amplitude of disturbance is an important parameter $\pm$ 1% of full scale can be nonsense.

Capturing the unknown

Fortunately we are now in a position to explore much more fully, at the theoretical stage, systems subject to wide ranges of conditions—as indeed we must. Computational aids are in fact making pneumatic systems in particular a more reasonable proposition for the rapidly developing aircraft design. To say this in front of aerodynamicists requires a certain amount of cheek of course, but they in particular are now benefiting from the advance in techniques. There is much to be learned from the aerodynamicists, and one thing in particular. This is the way in which aerodynamic theory has been supported by continuous experimentation. It is evident that they have reached the stage where it is generally accepted that experimentation is a very necessary phase of their activities. The servomechanism engineer has not yet reached the same eminence. It is to be hoped that this state of affairs will rapidly alter in the future.

Theoreticians generally have a bad name in certain quarters because they have been wrong, at least partially, so often. This has often been due to the sheer difficulty and complexity of the problems they have been asked to solve. Theory, after all, is simply a way of expressing what is known; that which is not known has yet to be captured and labelled, and theory cannot manage this on its own.

*Performance Engineer (Servomechanisms), H. M. Hobson Ltd.

CONTROL IN ACTION

Electro-mechanical control of drilling machine

Drilling a pattern of 600 holes of six different diameters under tape programme control

Fig. 1 Vero Auto-Drill tape-programme controlled drilling machine

BELIEVING THAT THE IMMEDIATE FUTURE for controlled machining lies with the comparatively simple and inexpensive electro-mechanical co-ordinate positioning type of machine, Vero Precision Engineering have developed the 'Auto-Drill', a programme-controlled turret-head drilling machine. Marketed at £3600 by Catmur Machine Tool Corporation, the Auto-Drill employs the Airmec Autoset (type N271) control system. This is non-electronic, operation being based on 24 volt d.c. switching by Post Office relays, a feature which is thought to appeal to the industrial user who may lack adequate maintenance facilities.

Spindle control and operation

The turret incorporates adjustable dogs to operate the fine-feed and depth-stop controls for each of the six drilling spindles, the whole indexing together. Microswitches signal to the Autoset 'operation started', to lock all table and spindle-movement controls and allow the punched tape to feed; and 'operation completed'. Spindle and speed selection is controlled in association with the Autoset by a three-wafer six-position rotary switch above the drill turret. Once the table is correctly positioned and the required spindle selected in accordance with the tape programme, the Autoset signals for air to be admitted to the air-hydraulic system, and the spindle descends until the fine feed microswitch is operated. The latter actuates a solenoid pilot-operated valve to divert hydraulic oil through an adjustable restrictor valve, and the spindle then descends at the required feed speed. This continues until the depth-stop microswitch is operated to reverse the air control and the spindle rises. The hydraulic oil is de-restricted during this movement to allow the spindle to return rapidly.

The dogs for 'fine feed' and 'depth stop' are adjustable in position to allow for their operation at any required range of feed traverse.

The appropriate turret is selected by a signal from the Autoset, the turret indexing round until the rotary switch contacts provide a signal coincident with the Autoset's demand, when the indexing relay closes to halt the turret. Machining cannot commence until the correct spindle has been selected and the table is in position.

Although primarily a fully automatic machine the control panel (on the left of the turret in Fig. 1) can be used for manual setting of the 'X' and 'Y' axes, the spindle number and speed selection. It is used mainly during setting-up. A lamp indicates whether the machine is on 'auto' or 'manual', and interlocks ensure that 'auto' cannot be used unless the drill motor is switched on. Other interlocks ensure that the 'up' or 'down' inching buttons for the spindle feed are inoperative when on 'auto' so that the programme cannot be interfered with once it has started.

Positioning the table

The Airmec Autoset system operates by accurately measuring the total angular rotations of the two lead screws. This is performed by sensing heads, or 'positioner units', which are directly connected to each of the lead screws on the longitudinal and cross traverses.

Each lead screw is driven by a reversible electric motor via a gear box and clutch unit. When a lead screw nears the required position, a signal is passed to the control unit, causing the motor to slow to half speed. Nearer the final position, a signal is passed by the positioner unit to a magnetic clutch in the gearbox-clutch unit, and this disengages direct drive and brings in a 25:1 reduction gear. The run-in to the final position then takes place at slow speed and, as the lead screw reaches its position, a further signal causes the magnetic clutch to disengage the drive and the table halts.

The final accuracy is, of course, dependent on the accuracy of the lead screws, although back lash has been avoided by arranging that the final approach always takes place in the same direction. When the table is moving from, say, 1 in. to 10 in., all movement may be in one direction and no back lash problem arises. When moving from 10 in. to 1 in., however, backlash is overcome by allowing the table to over-run down to 0·9 in. and then return to the 1-in. point for final positioning. The makers claim a repeat accuracy within 0·0005 in. of nominal, and the machine is guaranteed to provide an overall drilling accuracy of ± 0·003 in. Special jigging should reduce this to ± 0·001 in.

Autoset control

The basic method of control employed in the Airmec Autoset will be

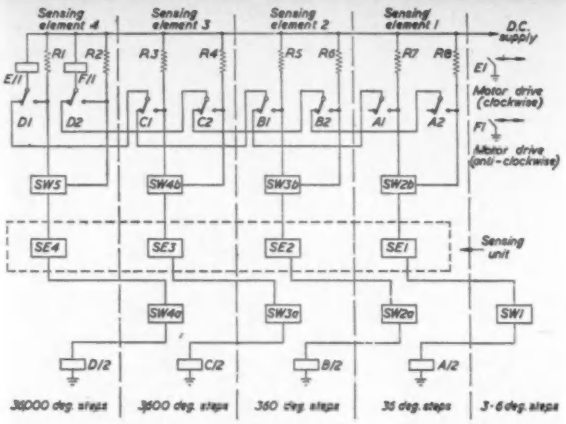


Fig. 2 A series of commutator sensing elements provides progressively finer settings in the Airmec Autoset system

apparent from the diagram Fig. 2. A series of commutator sensing elements SE1, SE2, SE3, and SE4, provide progressively finer settings. The control switches SW1, SW2a, SW2b, SW3a, SW3b, SW4a, SW4b and SW5 and relays D2, C2, B2 and A2 are each associated with their respective sensing elements. Contacts from these relays connect motor control relays E1 and F1 (forward and reverse motor drive) to the sensing elements in turn.

If any control switch is in a position such that its associated brush is not on a neutral sector, a path is formed for the associated relay. Thus, if element SE2 is not within the required angle of balance and the selected brush does not lie on the neutral segment, a path for operating relay B2 is formed via switch SW2a, SE2, SW3b and either resistor R5 or R6, to the power supply. Similarly, paths for operating relays A2, C2 and D2 are formed if the sensing elements SE1, SE3, and SE4 respectively are not so positioned that the selected brush lies on the neutral segment.

Relay contacts A1, A2, B1, B2, C1, C2, D1 and D2 are so arranged that the motor-control relays E1 or F1 are connected to sensing element SE4 if D2 is operated; to SE3 if C2, but not D2, is operated; and to SE1 if A2, but neither D2, C2 nor B2 are operated. In this way, control is automatically vested in the coarsest element still out of balance and is progressively transferred to the finest.

Tape programming

Control is centred around a programmer unit at the rear of the Airmec control cabinet, which appears on the right in Fig. 1. Some 70 ft of black vinyl tape, 4 in. wide and 0·004 in. thick, is used to store a programme, every tape having a capacity of 600 machining operations. The tape is fed from one roller to another and stopped in its correct position by a light shining through a locating hole on to a photo-transistor. The information is read by spring-loaded pins which bear on the stationary tape.

Machining starts as soon as the table is in the proper position. While one set of information is being acted upon, the tape progresses to the next information group, the programmer awaiting a signal from the machine that the operation is complete, after which the positioning and machining cycle continues. When the entire programme is complete, the tape rewinds automatically in readiness for the next workpiece.

Fourteen holes across the tape represent data for one machining operation. Each digit in the co-ordinate is represented by a column having five hole-positions, a number of holes being punched to a code in the position representing the digit required. Both the 'X' and 'Y' co-ordinates require five or six holes each, depending on whether the finest increments are 0·001 in. or 0·0002 in. A further column of five holes provides selection of facilities for ten tools and, if 0·001 in. steps only are required, two further columns will be available for tool facility selection.

On the Standard Vero Auto-Drill five columns only are used on each axis, the column for the 0·0002 in. digit on the 'Y' axis being used for spindle speed selection, and the equivalent column on the 'X' axis being left spare. The last—the fourteenth—column is employed for locking the 'X' and 'Y' ordinates, 'automatic stop' and 'tape run-back'.

A smaller hole for every information group halts the tape in the correct position whilst machining proceeds.

Economic considerations

The manufacturers claim that a Vero Auto-Drill at £3600 offers many economic advantages and suggest that, apart from the obvious increase in productivity which would be obtained by employing several machines under control of one man, savings of 200% have been obtained from the use of a single machine. The Auto-Drill cannot, of course, compete with press tools or multi-spindle drills for the very long runs. However, in the drilling of printed circuit boards, quantities greater than 5000 boards a week are said to be required before a press tool can be justified. Furthermore, on low-volume runs — say 100 components a week—the Auto-Drill is most attractive.

CONTROL IN ACTION

Rolls-Royce use controlled rotary table

GREAT ACCURACIES IN THE PRODUCTION of jet turbine engine components are being obtained at Rolls-Royce, Derby, with the aid of a new electronically-controlled positioning system. Developed by E.M.I. Electronics in collaboration with Optical Measuring Tools, the system uses a 30-in. rotary table and CONTROL understands that the results obtained by Rolls-Royce's Aero Engine Division over the past six months or more have been so satisfactory that Rolls-Royce have placed orders with E.M.I. for two further rotary-table positioning systems.

The controlled rotary table is being used for precise positioning when drilling holes in components for jet engines, although Rolls-Royce also intend to apply the technique to milling machines for producing radial slots in aero-engine components. It is particularly suitable for small-batch working as jigs and templates are unnecessary.

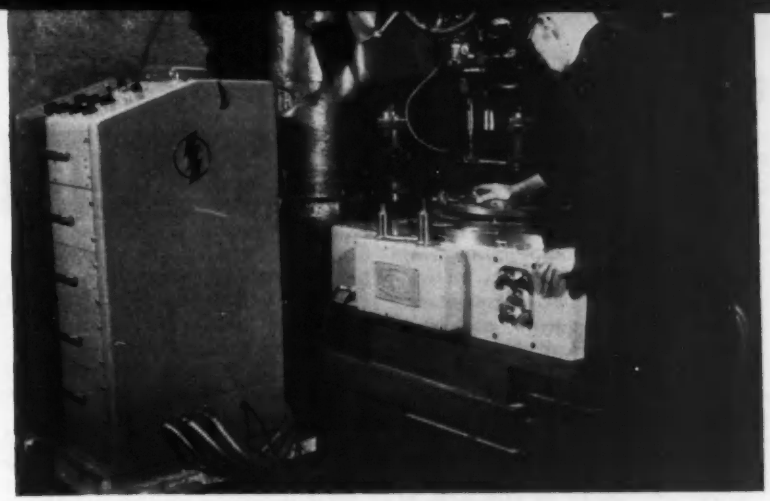
The setting accuracy is ± 3 seconds of arc with a repeatability of ± 1 second of arc, a degree of accuracy unaffected by mechanical wear. This is due to the use of an Inductosyn as the basic measuring element which indicates the actual movement of the table and not merely the movement of a worm drive or lead screw.

If several table settings are required, a programme of the angular settings is converted into punched tape, which is fed into a reader on the control console. For non-continuous operation, the operator presses the start button and the table moves to the first position, where it is automatically clamped, and the first machining operation is performed. The operator then presses the button to start

another cycle of operations, and so on.

For continuous operation, all movements are automatically controlled by the punched tape. The operator only has to fix the work-piece to the table, press the start button once and change tools later, if necessary. When making prototype or one-off work-pieces, a control tape is not required, for the system incorporates dial controls which can be set for any angular settings of the table, without loss of accuracy.

In all cases, the table rotates the shortest way round to the next position, either clockwise or anti-clockwise, thus saving considerable time on a job when several holes are required to be drilled. The speed of rotation is 1·5 rev/min.



Fixing a workpiece to the E.M.I. rotary table positioning system at the Derby factory of the Rolls-Royce Aero Engine Division

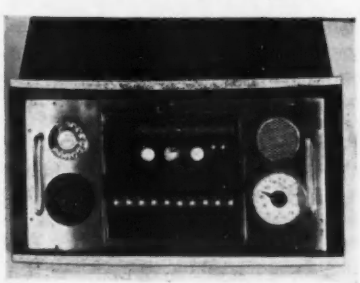
CONTROL IN ACTION

Power station telephone-controlled

THE SMALL 3 MW TURBO-ALTERNATOR at Princetown, Devon, which the South Western Electricity Board put into operation last month is believed to be first completely unattended electricity power station of its type. Designed to be complementary to the conventional large power plants, it is intended for operation at peak periods only, or for emergency use. The Board's duty is, of course, to provide power at the lowest possible price. The problem of inexpensive peak generation plus dependability of supply necessitates a station of low capital cost, which is reliable, capable of automatic starting and unattended running, and yet also capable of accepting full load within minutes.

The problems of cost, reliability and speedy acceptance of full load have been overcome by the use of a 4250 h.p. gas turbine by Bristol Siddeley, which is a modified version of the Proteus turboprop aero engine used in the Britannia aircraft. The Proteus has just completed a million engine hours in airline service, and, at Princetown, is expected to require little or no maintenance — possibly four routine visits a year, with an overhaul every ten years.

Datafonic remote control panel



The station is controlled remotely from the S.W.E.B.'s centre in Bristol, 100 miles from Princetown. The control system, which operates over ordinary Post Office lines, has been developed by Sound Diffusion (Auto-Thermatic) Ltd. and is known as Datafonic mark II control.

A mark I Datafonic equipment was originally developed to provide a central control room with supervisory facilities over remote unattended substations. These have normally been available in the past only by the use of equipment operating over privately rented Post Office lines which, when capitalized over a ten-year basis, represents a considerable investment.

The object of the mark I was, therefore, to operate over the national telephone network, and, by giving all information concerning breaker positions and other items in a *verbal* form, to avoid the need for both private lines and decoding equipment in the control room. The system was designed to dial or call a control room when equipment in the substation changed its state, and conversely, to give information when interrogated by an incoming telephone call.

The Post Office have given limited approval to the Datafonic system to be used on their subscriber lines where the user is a public utility body employing a continuously manned watch or control room.

The mark II equipment installed at Bristol enables the control engineer to carry out a total of up to forty control functions over the remote equipment. Typical functions are the 'start', 'stop' and 'throttle' controls on the remote turbo-alternator. These control facilities are supplemented by 22 pairs of indication lamps of which the turbo-alternator utilizes twenty. In addition, telemeter display facilities are also available in the Bristol control room for such quantities as megawatts, amps and volts. From this information the power factor of the distant alternator can be calculated.

The control console housing the indication, control and telemetering equipment is compact and is capable of extension to allow for the control of up to 24 additional substations.

The equipment operates over the national telephone network and the Control Engineer at Bristol can establish contact with the Princetown set by making use of the normal trunk call facilities. After obtaining the necessary information and making any required control operation he may instruct the remote equipment to disconnect itself from the telephone line.

In the event of a change in the running condition of the substation, the Datafonic equipment in the substation automatically engages its own exchange line and verbally requests the exchange operator to connect it with the Bristol control room. When the call is put through the Duty Engineer in Bristol hears the equipment announce its identity by voice, after which all control and telemetering facilities are available to him.

The Datafonic remote-control system is not only applicable to electricity generating and distribution networks, but also to other public utilities. In the gas industry, for example, a modified version can provide a range of telemetered information and control of both volumetric governor equipment and booster pumping equipment.

NEWS ROUND-UP

from the world of control

DATA PROCESSING

West Germans impressed

The 22 West German industrialists and professional men who made a five-day (November 30–December 4) tour of the computer industry are understood to have been impressed by British development, and to expect substantial sales to West Germany over the next few years. They considered British computers to be competitive in price and quality and felt that the advances made were far from widely known in Germany.

The Electronic Engineering Association, who organized the visit in collaboration with the Office Appliance and Business Equipment Trades Association, say the party were also impressed by: the extent to which British firms understood the need for servicing on the spot; the training facilities offered by British firms in computer utilization and by the experience which they had gathered in this field—including the use of computers for their own problems; and the extent to which German was used in technical discussions by the executives of the firms visited.

The West German Mission visited Ferranti, English Electric, E.M.I. Electronics, Standard Telephones & Cables, International Computers & Tabulators, A.E.I., Elliott Bros., and National Cash Register.

Automatic programming

A National Centre of Information on Automatic Programming of Digital Computers has been set up by the Department of Mathematics of Brighton Technical College. Its aims are to maintain a library, publish an annual review, provide a clearing house for information, organize small working conferences, and maintain contact with similar organizations abroad.

An Advisory Committee includes Dr. A. D. Booth (University of London), R. A. Brooker (University of Manchester), P. V. Ellis (I.C.T.), Dr. S. Gill (Ferranti), Dr. J. Howlett (U.K.A.E.A.), Dr. R. J. Ord-Smith (S.T. & C.), C. Robinson (English Electric), Christopher Strachey and A. E. Taylor (Remington Rand, Univac), J. H. Wensley (Computer Developments), and M. Woodger (Mathematics Division, N.P.L.).

Dr. Grace Hopper (Remington Rand, U.S.A.), Dr. L. Luckaszewicz (Mathematical Machines Laboratory, Polish Academy of Sciences) and Prof. H. Rutishauer (Institute of Applied Mathematics, Zürich), are corresponding members.

Further details are available from the Organizing Secretary, Richard Goodman, the Computing Laboratory, Dept. of Mathematics, Brighton Technical College.

De La Rue Bull's first order

At last month's opening of the first U.K. showroom and computer centre of De La Rue Bull Machines Ltd. (the Anglo-French concern formed last June) A. G. Norman, chairman of the company, announced that an order for a complete data-processing installation has been placed by The Royal Exchange Assurance Corporation. Value of the equipment involved is about £40,000 and consists of a Gamma 3 electronic calculator, a Bull sterling tabulator, a relay memory working in conjunction with the tabulator, an electronic sorter, electric punches and verifiers, a reproducer, a summary gang punch and an interpreter. The equipment, which will be delivered in March 1960, is to be used initially on dividend-payment problems.

The new showroom and computer centre of De La Rue Bull Machines Ltd. at 114–118 Southampton Row, London. This Anglo-French company was formed in June last year for the purpose of marketing a complete range of data-processing equipment

Pegasus for L. & M. Assurance

London and Manchester Assurance have placed an order for a £100,000 Pegasus data-processing system with Ferranti. To be installed at the assurance firm's headquarters in London in October, 1960, it will be used in the first instance for accounting and valuation work. This will involve the preparation of premium renewal notices, the associated control of payments, agency and company accounting and annual valuation of all life assurance policies.

A unified card file has already been set up, using I.C.T. equipment, and programmes for the computer are being prepared.

Pensions Leo commissioned

The Leo automatic office installed at the Ministry of Pensions and National Insurance's Newcastle offices has recently undergone commissioning tests and should now be operational. It is

intended to pay all 3000 weekly-paid officers stationed at Newcastle, and the 20,000 monthly paid officers at local and regional offices throughout England, with the aid of the Leo system. Other work will include the production of health statistics and the control of National Health Insurance claims.

97·8% efficiency

The commissioning tests were carried out under the control of Leo-trained Ministry personnel over a working week of 39 h 29 min. Good running time amounted to 37 h 44 min; the time lost due to technical causes (including re-runs) was 51 min, and 54 min were lost because of operating inefficiencies. On this basis Leo achieved 97·8% efficiency, satisfactorily exceeding the required criterion of efficiency.

I.C.T. in France

I.C.T. have received orders from three commercial concerns in France for their medium-sized general-purpose computer, the I.C.T. Type 1202. The capital value of the machines and ancillary equipment to be delivered is of the order of £60,000 in each case.

One order is from Etablissements Thibaud Gibbs Fragim et Cie, of Paris, manufacturers of toilet preparations. They propose to use their computer for invoicing, sales accounting, stock control, vehicle loading and payroll, etc.

Another is from Crédit Agricole, Avignon, an organization specializing in agricultural finance, who will be using their machine for a variety of banking tasks, including interest calculation.

La Cité Vie, Strasbourg, the third concern, is an insurance firm, interested in insurance accounting, statistics, premium advice notes, etc.

Airline seat reservations

I.B.M. have developed for American Airlines a centralized, electronic reservations system, the I.B.M. 9090, which is completely automatic and claimed to be the largest data-processing system in the world. It will handle every procedure to do with the sale, confirmation and control of an airline reservation, from the time a customer calls for information about a flight to his arrival at his destination.

The new system, based on two of I.B.M.'s large-scale, transistorized computers, will centralize in the New York headquarters of American Airlines the demands of over 1100 booking offices throughout the country. Communication over some 10,000 miles of telephone line, will allow any agent to confirm, alter, or cancel all or part of a passenger's booking, no matter where the original reservation was made. Seat inventories, maintained in the computer will allow agents to determine the availability of seats on any of the airline's flights. In addition, the I.B.M. 9090 will automatically send teleprinter messages to other airlines requesting space on their flights, quote fares, supply information about the current day's flights, and notify agents when special action is required.

The computers in the new system, each of which is capable of 210,000 logical decisions a second, are expected in the first stages to handle 85,000 telephone calls, 40,000 reservations, 30,000 exchange messages with other airlines, 30,000 fare quotations and 20,000 tickets daily, in addition to 7,500 reservations an hour in peak periods.

Card readers and punches

'Recommendations for card readers and punches' has been published by the Electronic Engineering Association, 11 Green Street, Mayfair, London, W.1. This document comprises general data on the basic requirements of computer manufacturers for card readers and punches. Its objects are: to promote the adoption of such designs and production practices as have proved, to date, to be desirable; and to contribute to any national standards on the subject. The document is technical and does not discuss contractual matters. It is not, of course, binding on members of the E.E.A.

Solartron e.r.a. ordered

Solartron have received an order for an e.r.a. (electronic reading automaton) from Domestic Electric Rentals who require it for rental and credit-sales accounting. The e.r.a. will read directly information recorded by National Cash Register machines at each branch of the radio-television organization. This information, which will include the customer's account number and rental payment amount, will then be automatically punched on to 80-column I.C.T. cards for subsequent use in a standard punched-card installation.

Simlac analogue computers

The name Simlac has been adopted by Short Brothers & Harland as the trade mark of a new range of general-purpose analogue computers they are developing. The Simlac range incorporates all the automatic aids necessary to ease the handling of complicated problems, including those of nuclear kinetics. It employs new wiring techniques and a patching system which avoids cord-clutter. There are also an improved push-button selector system and associated problem check. Setting-up is claimed to be fool-proof and the component absolute accuracy is better than 0·01%.

The standard Simlac is a 112-amplifier linear computer, but the basic design is such that individual requirements can be met by plugging the specified components into standard Post Office racks. Provision is made for the incorporation of special non-linear function units if required.

—— PETROLEUM ——

Equipment for Dinslaken

During a recent visit to Evershed and Vignoles' Chiswick works, CONTROL saw instrumentation and control equipment for the Dinslaken oil refinery of the B.P. Benzin und Petroleum Aktiengesellschaft in Germany. The refinery, which is being constructed by Kellogg International, is designed for a throughput of 100,000 barrels a day.

The Evershed control desk (illustrated) contains process controllers, indicating and recording facilities, supervisory instruments and manual control provisions for two crude distillation plants, a hydrofiner, a catalytic reformer, and a re-distillation unit.

Of the 120 separate control loops provided, some are inter-related by resetting and cascading arrangements. Temperature measurements from 340 different points throughout the refinery are effected by thermocouples and used for indication or control purposes. There are also two analysis recorders for percentage hydrogen and percentage oxygen.

In-line scanning is used extensively to reduce the number of technicians required for routine operation. During satisfactory operation an unbroken shadow line is presented to the operator, and any break in this line immediately pin-points the part of the refinery where a deviation from desired conditions has occurred; it also gives an indication of the magnitude and direction of this deviation.

Panel space is saved and a simple layout achieved by the use of two recorders only for each section of the panel—apart, that is, from recorders for standard temperature measurements. Each recorder handles plant parameters from sixteen different points throughout the refinery by the use of a plug-in selection system. Plug-in recording is possible because the Evershed electronic repeater mea-

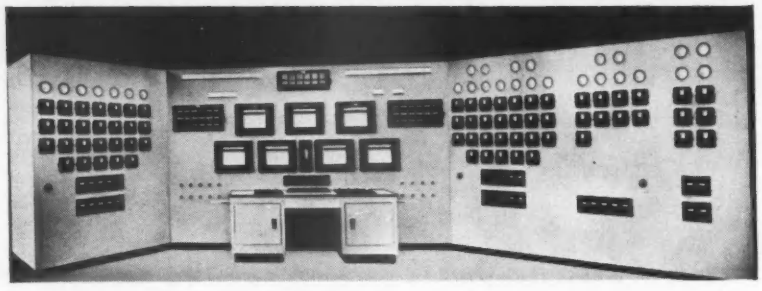
surement system, which is employed, automatically compensates for any additional instruments which may be temporarily inserted into the measurement circuit.

In general, the temperature-measuring circuits consist of thermocouples feeding into potentiometric recorders via telephone-type switchboards. In some loops, however, d.c. amplifiers convert the thermocouple output voltages into signals suitable as measured-value inputs for process controllers.

Process control

Evershed Mark 4 controllers are used, and generate proportional, integral and derivative terms. Their outputs operate electro-pneumatic valve positioners, or converters which establish air pressures proportional to the electrical control signals.

Most of the plant-mounted transmitters are of the Evershed electronic repeater type. Flows, levels, pressures etc. are made to impose a turning moment on a pivoted beam. One end of the latter carries a coil in a magnetic field, and on the other end a contact is arranged to travel between two fixed contacts. As the beam is deflected a signal is transmitted via the contacts to electronic equipment and fed back in such a manner as to oppose the turning moment generated by the particular parameter. The current through the coil is thus proportional to the value of the measured parameter, and indicators and recorders can be directly calibrated.



Control panel for the Dinslaken (West Germany) oil refinery. This panel, which was exhibited by Evershed & Vignoles recently, accommodates 120 separate control loops

Each process controller is fed with the measured value signal and any difference between this and the desired value is applied to a proportional amplifier. The output of the latter forms the proportional term of the controller's output signal. The deviation also provides the input to integral and derivative networks and amplifiers, the outputs of which are added to the proportional signal so that a three-term control signal is generated.

In the electro-pneumatic valve positioners and converters a coil in a magnetic field is arranged to receive the controller's output signal. The position of the coil depends on the magnitude of the signal and is transmitted through a lever to a flapper which operates in conjunction with the nozzle of a non-bleed air relay. In this manner the electrical signal provides a pneumatic signal for the control of valves. A feedback arrangement operates when the positioner or converter attains the required position, the force generated by the coil and magnet being balanced by a force derived from the pneumatic circuit.

STEAM

Autcontrolled boilers at R.-R.

The use of Kelvin-Hughes automatic boiler controls on six boilers at Rolls-Royce, East Kilbride, has led to a 5·3% increase in efficiency; this in spite of the fact that the efficiency under manual operation was already higher than the average.

High efficiencies maintained

Accurate and detailed reports of loading and fuel consumption had been maintained over a long period, so comparisons between automatic and manual control could be made under all load conditions. Generally speaking an increase of 5·3% efficiency was achieved over a three-winter-month test period, the system maintaining an average of 76·9% over the 71·6% obtained by manual firing. A significant factor arising out of a study of the available figures was that, in a comprehensively instrumented and well engineered system, efficiencies bordering on the 'automatic' figures can be obtained by manual operation. The main advantage of the automatic system is understood to be its ability to maintain high-efficiency working over sustained periods.

The boilers comprise six Wilson Super Economic types in two groups of three, with two Weir direct-acting feed pumps sited between the groups. Coal is delivered through a grid to the boot of a bucket elevator and thence to the chutes of the hoppers. Hodgkinson low ram stokers driven by constant speed a.c. motors are employed. Ash is raked directly on to a submerged conveyor belt which runs below the whole length of the raised firing platform to an external disposal hopper.

A master steam-pressure controller situated in the Superintendent's office is connected to the main steam header and provides an advance warning of fluctuating loads. Signals that are proportional to the fluctuating steam pressures are relayed by the master controller to the individual combustion controllers regulating the coal feed and airflow to each boiler.

Coal feed is regulated by the cyclic operation of the constant-speed motors driving the mechanical stokers, the running time being proportional to the load as indicated by the master controller. Air flow control is effected by a motorized damper, operated through a push rod, and reduction gear.

Pressure difference across the boiler passes is measured and fed to a diaphragm unit. The output of the diaphragm is opposed by a control spring which is tensioned by a square-law cam moving in response to the load signals. The resultant force positions a switch which controls the damper motor. Thus the air flow is subject to closed-loop control and is independent of the characteristic of the damper motor.

Provision is made on the combustion controllers to enable the fireman to change over to manual control or to adjust the heat regulation at will. The controllers are also balanced to permit load sharing and once set should require no further adjustment.

Kelvin-Hughes assess the fuel savings which accrued at Rolls-Royce over the three-month period at £1603—in other words more than the cost of the installation.

LABOUR

Scientific man-power

The annual report of the Advisory Council on Scientific Policy was published on December 8th, 1959 (Cmnd. 839, price 1s. 0d.). (The Council is a standing committee advising the Minister for Science.) The results of a survey of scientific and engineering man-power were published simultaneously in a separate White Paper (Cmnd. 902, price 3s. 0d.).

In its report the Council expresses satisfaction with the increased proportion of scientists in civil industry and the decreased share in defence work.

The growth in the annual supply and employment of newly qualified men has exceeded the expectations of 1956, when the results of a 1955 survey were published. But the Council sees no indications that more qualified scientists are being produced than are necessary.

The Council believes that carefully designed experiments using earth satellites can help to solve a number of important scientific problems, and may often be the most economic way of doing so; but it considers that the cost of lunar, planetary or solar probes would be too great for this country alone, and advocates international co-operation on such work.

The report on scientific man-power brings up to date the information in the 1956 report on the same subject. The earlier publication was based on an enquiry by the Ministry of Labour and National Service concerning both the number of qualified scientists and engineers in Great Britain and employers' forecasts of requirements by 1959. The present paper contains the results of a renewed enquiry, the employers' forecasts of requirements extending this time to 1962. The report indicates that the employment of qualified men increased at a rate of about 6% a year during 1956–58. Employers have said that they would like to achieve an increase of 7% during the next three years (1959–61). No less than 41,000 scientists and engineers qualified in 1956–58, compared with a forecast of 36,000 by the Council's Committee on Scientific Man-power. But at the beginning of 1959 employers reported over 6000 vacancies in manufacturing industry alone. The Committee estimates that over 51,000 men will have qualified in the three years 1959–61, but that the numbers available for employment in Great Britain will still fall short of employers' forecast requirements. A shortage of mathematicians, physicists and chemists is expected to continue.

—MACHINE TOOLS—

A.E.I. systems

The accompanying photograph shows a row of electronic control cubicles for the machine tool industry, in the final stages of manufacture at the New Parks Factory, Leicester, of the A.E.I. Electronic Apparatus Division. Cubicles of the type illustrated are used to provide accurate control for the feed motors and spindle speed of ram-type boring machines. The cubicle in the foreground is for controlling two 20 h.p. 1500–850 rev/min motors for driving the feed motion of a machine tool and one 100 h.p. spindle drive motor which has a speed range of 1500–500 rev/min.

A.E.I. has developed a system of co-ordinate setting for vertical jig borers and horizontal boring machines, etc. It is claimed that, depending on the quality of the machine tool, this equipment will position the work in two dimensions to an accuracy of 0·0002 in., the information for each position being fed in automatically from punched card or punched tape. This can also be adapted to 'staircase' milling where a series of punched cards is automatically fed in, in a given sequence, to move the milling cutter through a required path.

Electronic control cubicles for machine tools near completion at the New Parks, Leicester, factory of A.E.I.'s Electronic Apparatus Division

—— BUSINESS ——

Solartron sold

Firth Cleveland are to acquire a 53·125% interest in Solartron at a cost of £900,000 and have agreed to make an offer on or before July 31, 1961 for any remaining shares at not less than £3 a share. Firth Cleveland's Chairman, Charles W. Hayward, will become Chairman of the Solartron Board, while John E. Bolton will be Deputy Chairman and Managing Director.

Ultra re-organize

Two subsidiary companies are being formed by Ultra Electric (Holdings) Ltd. Ultra Radio & Television Ltd. will handle domestic radio and television and have as its subsidiary Pilot Radio & Television Ltd., which Ultra acquired last year, and Ultra Electronics Ltd. will handle the activities formerly carried out by the Special Products Division. The existing Ultra chairman, Edward E. Rosen, remains chairman of the holding company and the subsidiaries and A. V. Edwards has been appointed managing director of each company.

The other members of the Board of Ultra Electronics are L. R. Crawford (general manager), Dr. F. W. Storeman (chief engineer), J. S. Williams (works manager), and E. R. Wright (commercial manager).

Gas detectors

A new company, Willis Instruments Ltd., has been formed at Field Road, Busby, Lanarkshire, to manufacture gas detecting instruments and alarms to certified and approved designs. They will also provide 24-hour servicing and maintenance facilities for all types of electrical and electronic scientific instruments. CONTROL understands that Willis Instruments are negotiating the establishment of a service centre at Busby with several British instrument manufacturers. The company's managing director is A. N. Willis, and other directors are G. Brown, a director of George Brown (Marine), and H. Kerr.

—— MISSILES ——

S.I.T. rocket Symposium

The Society of Instrument Technology and the British Interplanetary Society are to hold a one-day Symposium in London on September 1, 1960, during which approximately eight papers will be presented on 'Rocket and Satellite Instrumentation'. The papers proposed are as follows: 'Outline of the investigations planned for the British space programme'; 'A design study on a communication satellite'; 'A digital data reduction system for use in the static testing of rocket motors';

'Transducers for rocket motor testing'; 'The measurement, transmission and recording of data in the Skylark'; 'Ultra-violet measurements from satellites'; and subjects to be decided later.

The object of the Symposium is to indicate the fields of scientific knowledge which have been opened up by experiments in the upper regions of the atmosphere and in outer space and to describe the kind of instrumentation which has either been used already or will be required for future research.

B.C.A.C.

Group B's executive

At the Annual General Meeting of Group B, the British Group for Computation and Automatic Control of the British Conference on Automation and Computation, the executive committee for 1960 was reconstituted. The chairman is J. F. Coales, with R. Hindle and H. W. G. Gearing as vice-chairmen and S. M. Rix as hon. treasurer. The hon. secretary is W. Bamford, and the other members of the committee are Dr. A. D. Booth, N. Clarke, E. C. Clear Hill, W. C. F. Hessenberg, N. C. Pollock and Professor E. J. Richards.

One substantial activity which the Group has undertaken, in collaboration with Group A, is the sponsoring of the British contribution to the First Congress of the International Federation of Automatic Control (I.F.A.C.) which is being held in Moscow from June 27 to July 6, 1960. As the number of papers submitted by British authors exceeded the time and space allocated by the organizers of this Congress, arrangements are being made for a British Convention on this subject to be held in London in September 1960, at which the surplus of suitable papers will be presented.

Further details concerning the I.F.A.C. Moscow Congress may be obtained from the Hon. Secretary, Group B, B.C.A.C., c/o The Institution of Electrical Engineers; the arrangements for the British Convention referred to above are in the hands of the Hon. Secretary, Group A, B.C.A.C., c/o The Institution of Mechanical Engineers.

IN BRIEF

Electrical Connector Division of Electro Methods Ltd., under Divisional Manager D. P. Wright, is now at Hitchin St., Biggleswade, Beds. (Telephone: Biggleswade 2086.)

Morganite potentiometers and resistors are no longer handled by Siemens Edison Swan—now A.E.I. (Woolwich), and will in future be sold to wholesalers and retailers by The Radio Resistor Co. Ltd., 50 Abbey Gardens, London, N.W.8.

Airmec electronic instruments and industrial control equipment will be exhibited in the Napier Hall, Hide Place, Vincent Square, London, S.W.1, from 18-22 January. Tickets free from Airmec Ltd., High Wycombe, Bucks.

Power-operated manipulator valued at £12,000 has been ordered from G.E.C. for use at the C.E.G.B.'s Berkeley, Glos., nuclear research laboratories in handling irradiated fuel elements etc.

Information engineering: a twelve-month M.Sc. course starting on October 1, 1960, is open to suitably qualified students. Subjects available cover communications, radar, computers, and control systems. Engineers seconded from industry for five-week periods may be admitted to courses of lectures on individual topics. Details: D. A. Bell, Supervisor of Graduate Courses, The Electrical Engineering Dept., The University of Birmingham, Edgbaston, Birmingham, 15.

E.M.I. broadcast equipment will be handled in Canada by Canadian General Electric following a new agreement between the two concerns.

Semiconductor Division of G.E.C. and Plessey Group member Semiconductors Ltd. have arranged for their technical sales forces to handle information on each others products.

Precision wirewound resistors of Alma Components Ltd. are now handled in Sweden by AB Solartron of Hedinsgatan 9, Stockholm NO.

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society. Brit. I.R.E. British Institution of Radio Engineers. I.E.E. Institution of Electrical Engineers. R.Ae.S. Royal Aeronautical Society, S.I.T. Society of Instrument Technology.

MONDAY 11—WEDNESDAY 13 JANUARY
6th National Symposium on *Reliability and Quality Control in Electronics*. Washington. Details: R. Brewer, General Electric Co. Ltd., Wembley, Middx.

MONDAY 11—SATURDAY 16 JANUARY
C.O.S.P.A.R. First International Space Science Symposium, Nice

WEDNESDAY 13 JANUARY
Discussion on *The Reliability, Maintenance and Serviceability of Computers*. Brit.I.R.E.

THURSDAY, 14 JANUARY
Future of Automatic Control on Fixed Wing Aircraft by G. A. Whitfield. R.Ae.S., at I.Mech.E.

MONDAY 18—FRIDAY 22 JANUARY
44th Physical Society Exhibition, Royal Horticultural Society's Halls, Westminster

TUESDAY 19 JANUARY
Discussion on *Superseding the Ratio Arms in a.c. Bridges* (Opened by C. G. Mayo). I.E.E.

WEDNESDAY 20—THURSDAY 21 JANUARY
Managerial and Engineering Aspect of Reliability and Maintenance of Digital Computer Systems. I.E.E.

TUESDAY 26 JANUARY
Symposium on *Flame Failure Detection*. S.I.T.

WEDNESDAY 10—FRIDAY 12 FEBRUARY
Solid State Circuits Conference, Philadelphia. Details: The Chairman, 1960 Solid State Circuits Conference, General Electric Co., Electronics Laboratory, Electronics Park, Syracuse, New York, U.S.A.

THURSDAY 11 FEBRUARY
Measurement, Automatic Control and Data Reduction as Applied to a Cyclic Plant by T. A. Lucas. S.I.T.

WEDNESDAY 17 FEBRUARY
Faraday Lecture—*Electrical Machines* by Prof. M. G. Say. Central Hall, London

THURSDAY, 18 FEBRUARY
Missile Control Problems by D. Best. R.Ae.S., at I.Mech.E.

FRIDAY 19—TUESDAY 23 FEBRUARY
Third Salon International de la Pièce Détachée Electronique (Electronic Component Show), Parc des Expositions, Porte de Versailles, Paris.

MONDAY 22—FRIDAY 26 FEBRUARY
First Engineering Materials and Design Exhibition and Conference. Earls Court.

WEDNESDAY 16 MARCH
The Simulation of a Large Chemical Plant on an Electronic Analogue Computer by A. H. Doveton and K. C. W. Pedder. S.I.T.

SATURDAY 12—MONDAY 21 MARCH
42nd International Trade Fair. Lyons

MONDAY 21—TUESDAY 22 MARCH
Discussion on *The Computer in Production*. I.Mech.E.

TUESDAY 29 MARCH
Application of Transistors in Instrumentation by G. G. Bloodworth. S.I.T.

Looking Further Ahead

TUESDAY 5—SATURDAY 9 APRIL
Ninth Electrical Engineers Exhibition. Earls Court

THURSDAY 7 APRIL
The Electronic Computer as a Unit in an Automatic Electronic Data Processing System for Missile Trials by W. C. J. White and D. L. Overheu. S.I.T.

MONDAY 25—SATURDAY 30 APRIL
Production Exhibition, National Hall, Olympia

TUESDAY 26 APRIL
Control Section Annual General Meeting 6.15 p.m. *Some Recent Advances in Industrial Electrical Control Techniques*. S.I.T.

TUESDAY 3—FRIDAY 13 MAY
Mechanical Handling Exhibition and Convention. Earls Court

WEDNESDAY 11 MAY
Sixth Conference of Standards Engineers, Connaught Rooms, London

MONDAY 23—SATURDAY 28 MAY
Instruments, Electronics and Automation Exhibition, Olympia

FRIDAY 10—SUNDAY 26 JUNE
British Exhibition, Coliseum Building, New York

FRIDAY 24 JUNE—FRIDAY 8 JULY
International Machine Tool Exhibition. London

MONDAY 27 JUNE—WEDNESDAY 6 JULY
Moscow Congress for Automatic Control. Details Hon Sec. Group B, B.C.A.C., c/o I.E.E.

THURSDAY 21—WEDNESDAY 27 JULY
Third International Conference on Medical Electronics. Olympia

MONDAY 29 AUGUST—FRIDAY 2 SEPTEMBER
Conference on Semiconductors. Prague

MONDAY 5—SUNDAY 11 SEPTEMBER
S.B.A.C. Flying Display and Exhibition. Farnborough

WEDNESDAY 21 SEPTEMBER—SATURDAY 1 OCTOBER
International Factory Equipment Exhibition. Belle Vue, Manchester

WEDNESDAY 19—WEDNESDAY 26 OCTOBER
Interkama International Congress and Exhibition for Instrumentation and Automation. Düsseldorf

PEOPLE IN CONTROL

by Staffman

PHELPS CHAUVEL NORMAN
entente cordiale

The formation of an Anglo-French company, the British component of which — De La Rue—has a French name and the Gallic component—Machines Bull—a very English name, provided a certain amount of amusement at the recent opening of De La Rue Bull Machines' Southampton Row computer centre (see *News Round-up*). My heading illustration shows (right) H.E. The French Ambassador, Monsieur **G. Chauvel,** examining a data processor under the guidance of De La Rue Bull Machines' General Manager, Dr. **H. J. Phelps.** On the far right is **A. G. Norman,** De La Rue's M.D. and Chairman of the new computer firm.

TRIGGS
electronics

BURNETT
Instruments

The Electronics Group of National Cash Register is to be known as N.C.R. Electronics in future. It will be headed by **D. H. Triggs** as Manager responsible for sales, with **R. G. Wadsworth** as his Assistant Manager. **H. L. S. Orde** is Joint Manager responsible for commercial and technical matters, with **A. H. Beaven** as Assistant Manager. **T. S. Chandler** becomes Administration Manager. They will be directly responsible to **W. B. Woods,** Director of Sales at National Cash.

N.C.R. Electronics will continue to be responsible for the National-Elliott 405 data processor and for operating the Data Processing Centre in Marylebone Road, London. However, I understand that it 'is expanding its resources to handle new developments which have now reached an advanced stage'.

There have been a few changes in the Metal Industries Group. I was sorry to hear that **J. H. Rawlings** had been obliged, because of an indisposition which is likely to continue for some time, to relinquish the position of Managing Director of Avo. He is, however, remaining on the Board as Deputy Chairman and also on Brookhirst Igranic's Board. **S. R. Wilkins** succeeds him as Avo's M.D. and also joins the Board of Taylor Electrical Instruments. **E. Strauss** has been appointed Director and General Manager of Taylors and also joins the Avo Board.

R. E. Burnett, General Manager of Marconi Instruments, has been elected to the Board and appointed Managing Director. Prior to becoming Marconi Instruments' G.M. in 1956, he was Deputy General Manager and, before that, assistant to the General Manager of Marconi's Wireless.

Dr. George Macfarlane, a Deputy Chief Scientific Officer at R.R.E., Malvern, has been appointed Deputy Director of the N.P.L. He succeeds Dr. **Edward Lee** who became Director of Stations and Industry Divisions at D.S.I.R.'s headquarters. Lee was Director of Operational Research at the Admiralty before going to the N.P.L.

I hear from **J. M. Chuchla,** Managing Director of Electrical Remote Control Co., that they have formed a new company, Equipment and Services Ltd., whose Managing Director is **Paul Gotley.** I gather that the new company's forte is the quick delivery of electrical timing and control equipment manufactured to specific requirements. Apparently much of this equipment is not manufactured for stock and it is quite usual for users to be faced with costly delays. Equipment and Services hold staff, production space, stocks of components and pre-assembled parts to meet sudden demands. The address is Bush House, Bush Fair, Harlow, Essex, and the telephone number Harlow 24287.

V. Thomas, Managing Director of Thomas Industrial Automation of Altrincham, writes me that **P. Snowden** has been appointed to the Company's Board. Snowden, who was trained in radio and telecommunications, has for some time been engaged on the development and production of industrial electronic equipment. He will control the production side of the Company.

Technical liaison with Government Departments and Research Establishments will be the chief responsibility of **R. C. Parry,** who joins Mullard as Government Liaison Officer covering valves, tubes, semiconductors and components. Parry, who was with Marconi's Wireless, will be administratively responsible to **H. Malleson,** head of Mullard's Government and Industrial Valve Division.

I am intrigued by the news that **V. G. P. Weake** is taking up the appointment as Chairman of the newly-formed Derritron Group of electronic companies—'details of which will be given at a later date'. He has relinquished his directorships of Pamphonic, W. Bryan Savage and Pye Marine in order to do this. Weake is a Director of Eastern Nigeria Broadcasting, Chairman of Audio Fairs, and Chairman of the Society of Environmental Engineers.

New for Control

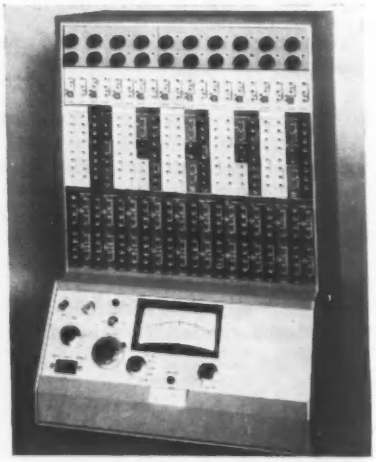
A monthly review of system components and instruments

ANALOGUE COMPUTER

transistorized, versatile

The latest of the analogue computers from Electronic Associates is the TR-10. This desk-size unit is 16 in. wide, 24 in. high and 15 in. deep, and weighs 93 lb (fully expanded). The power consumed is less than 50 W.

The computing accuracy is claimed to be 0·1% and the standard basic TR-10 comprises 5 dual-coefficient setting potentiometers, 5 dual operational amplifiers, 2 dual integrator networks, reference



Compact computer

and power supplies. For more complex problems a wide range of linear and non-linear plug-in components are available.

An X-Y recorder and a 2-channel strip-chart recorder can be supplied as external read-out equipment for use with the TR-10.

Further information is available from Electronic Associates Ltd.

Tick **No 501** on reply card

SPEED CONTROLLER

for electric motors

The range of Magnedyne electronic speed controls for electric motors is now being marketed by Metrix Instruments Ltd. Designed for use with motors from 0·01 to 10 h.p., the controls offer a wide range of speed control with a fine degree of adjustment, a high efficiency, and constant speed at any one setting for wide and rapid changes of load conditions.

The control equipment is supplied from normal a.c. mains and the d.c. motors are fed from a rectified supply to both the field and armature windings. The control of speed is effected by varying the reference voltage applied to the armature, which may be controlled manually or automatically. The control embodies a simple electronic amplifier together with an amplifier of the magnetic saturation type. If the armature voltage drifts from the value selected at any position of the speed control, the electronic amplifier reacts automatically and instantaneously, and via the magnetic amplifier regulates the energy necessary to maintain the speed of the motor.

The speed-torque curves are almost flat, and the characteristics therefore resemble those of an induction motor combined with the advantages of a d.c. motor.

It is also possible to control the speed of the motor to within 0·1–1·0% by means of a tachometer circuit controlled by the motor and feeding back the error signal.

Tick **No 502** on reply card

HUMIDITY INDICATOR

with a unique thermistor

The Hygrophil relative humidity indicator uses a thermistor as a detecting element. The thermistor used was developed by Ultrakust-Gerätebau and overcomes many of the conventional troubles of this type of semiconductor. Owing to the small size and heat capacity of the detecting element the instrument requires only a small sample amount of air, and this has a quick response time (about 25 s on the wet bulb).

Quick on the draw

The temperature range is − 10 to 80°C or 10 to 177°F, and for relative air moisture content the maximum accuracy is 0·50%.

The instrument comprises a pistol and an indicating instrument. The butt of the pistol houses a dry battery which drives a small fan, drawing air in through the pistol barrel over the elements. The diameter of the barrel is only ½ in. and it can be extended by means of extension tubes. A clockwork-fan-operated unit is also available for use in inflammable atmospheres.

The instrument can be supplied by Headland Engineering Developments Ltd.

Tick **No 503** on reply card

X-Y PLOTTER

error less than 0·15%

An X-Y plotter from Houston Instrument Corporation is designed to operate from differential transformers. It may be

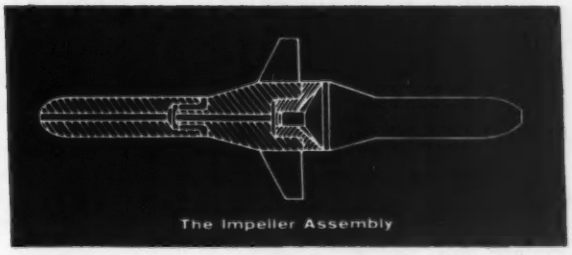
High detection-sensitivity

used to plot small mechanical movements or any related variables which can be converted to mechanical movements. Multiplication factor is accurately adjustable to 1000:1, movements of 20 μin. are readily detectable.

Standard 24 × 36 in. D size paper or 24 in. roll stock graph paper may be used. A dual vacuum hold down system also permits the use of half size sheets. Conveniently located on top bezel are illuminated push buttons for operation of the power, stand-by, vacuum hold-down load-operate and electric pen-lifter

New British flowmeter

Meterflow Ltd announce an entirely new range of flowmeters, developed and made in Great Britain. These Meterflow instruments are of the impeller type, the impellers—the most critical part of the assembly—being of radically new design. The range covers pipe diameters from $\frac{5}{8}$"–8" and is suitable for all corrosive and non-corrosive liquids and liquid oxygen, at temperatures between —180° and +200°C. There is built-in compensation for friction at different speeds, and for the cooling effect of liquid oxygen, so that Meterflow meters maintain an accuracy better than $\frac{1}{4}$% over a range of 8:1, and repeatability of 0.1%. The equipment is available with all associated electronic gear including frequency d.c. converter. The prices of this range of precision flowmeters are most competitive. Meterflow Ltd would like to send you full details of this new development.



The Impeller Assembly

Patent Applied For

Meterflow

Meterflow Ltd *Precision Measuring Instruments*
North Feltham Trading Estate, Feltham, Middlesex
Telephone: Feltham 5876

Tick No 68 on reply card for further details

switches. The less frequently used zero controls and ten-turn multiplier dials are on the front panel. Signal, reference and rebalance circuits are 400 c/s originating from a built-in tuning fork oscillator. The servo systems operate from 50–60 c/s supply frequency. Pen speed with standard servo is 2 in/s. Pen speeds of up to 20 in/s and electronic sub-assemblies to operate from low-level d.c. inputs are available on special order.

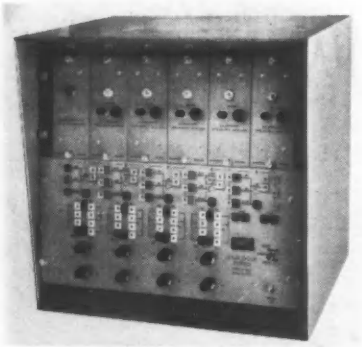
Tick **No 504** on reply card

ANALOGUE COMPUTER

for training

An analogue training device (the TY 963) has been announced by the Solartron Electronic Group Ltd.

Basically it is a simplified analogue computer intended for educational applications. It is capable of representing any form of linear second-order differential equation using the built-in computing components and demonstrating, for example, the effects of velocity and acceleration limits using external diodes as additional computing impedances.



Self-contained computer

Incorporating five operational d.c. amplifiers, the computer is a self-contained unit, complete with stabilized power supplies and patching and control facilities. Interchangeability of component assemblies permits elements from the analogue tutor to be incorporated into more complex analogue computer installations.

Tick **No 505** on reply card

STARTER

for squirrel-cage motors

A new type of starter for squirrel-cage motors has been developed by Lee Guiness from the invention by M. Beyrard of France. The basis of the device is a liquid primary-resistor, in which the resistive element is an electrolyte with a negative temperature-coefficient. This is kept in circuit until its resistance has fallen to about one-fifth of its initial value, and it is then short-circuited by a contactor.

The main advantages are the smooth torque/speed relationship, which is comparable with that of an auto-transformer starter, and low cost.

The Statormatic covers a power range from 7½ to 100 h.p. in six stages, at prices ranging from £68 to £202 according to size, voltage input, and whether normal or heavy duty.

Tick **No 506** on reply card

PORTABLE MONITOR

for background radiation

A lightweight portable monitor has been developed by Plessey Nucleonics Ltd. for the measurement of background radiation. Detection in the monitor (type PNI 1072), is accomplished by a built-in halogen-quenched Geiger Müller tube with measurement on a transistor ratemeter giving direct reading of dose rate on a 2½ in. scale moving-coil meter. The instrument has a range of from zero to 3 milliroentgens on a two decade quasi-logarithmic scale, with a minimum scale calibration of 30 microroentgens. The unit is powered by a 9 V dry battery and weighs only 8 lb.

Tick **No 507** on reply card

SERVO MULTIPLIER

with less than 1° phase lag

A new, low-inertia servo multiplier (type TJ 725) has been introduced by the Solartron Electronic Group Ltd.

It will operate with less than 1° phase lag at full-scale amplitude up to 10 c/s. It permits multiplication of up to five analogue variables by one other variable, or the generation of up to the sixth power of one variable. A six-section potentiometer is standard, one section having additional taps for the connexion of loading resistors to achieve special functions of a variable. The multiplier is also available as a servo resolver, in which there are five potentiometer sections, three linear, and two conforming to sine/cosine law.

Small phase-lag

Both these new non-linear computing units are self-contained and incorporate transistorized power supplies.

The full scale input (servo) is ± 100 V with an input impedance of 1 megohm. The static accuracy is ± 0·5% of full scale with all centre taps earthed, and all wipers loaded with 1 megohm and ± 0·25% of full scale with zero input to servo. The drift is less than 100 mV/week. The transient response is zero to full-scale step response less than 30 ms.

Tick **No 508** on reply card

AMPLIFIER

for use with velocity pick-ups

A new velocity pick-up amplifier (type A.W.E. 138/1) is suitable for use with seismic or non-seismic pick-ups, such as the Philips type 9261. The dial indication is peak amplitude, seven switched ranges giving full scale deflexion of 0·3–300 × 10^{-3} in. A relative accuracy of better than ± 5% is claimed for all ranges.

The unit also has an output suitable for a recorder having an input impedance of more than 200 kilohms. It weighs only 15 lb, is mains operated, and is made by Armstrong Whitworth Equipment.

Lightweight

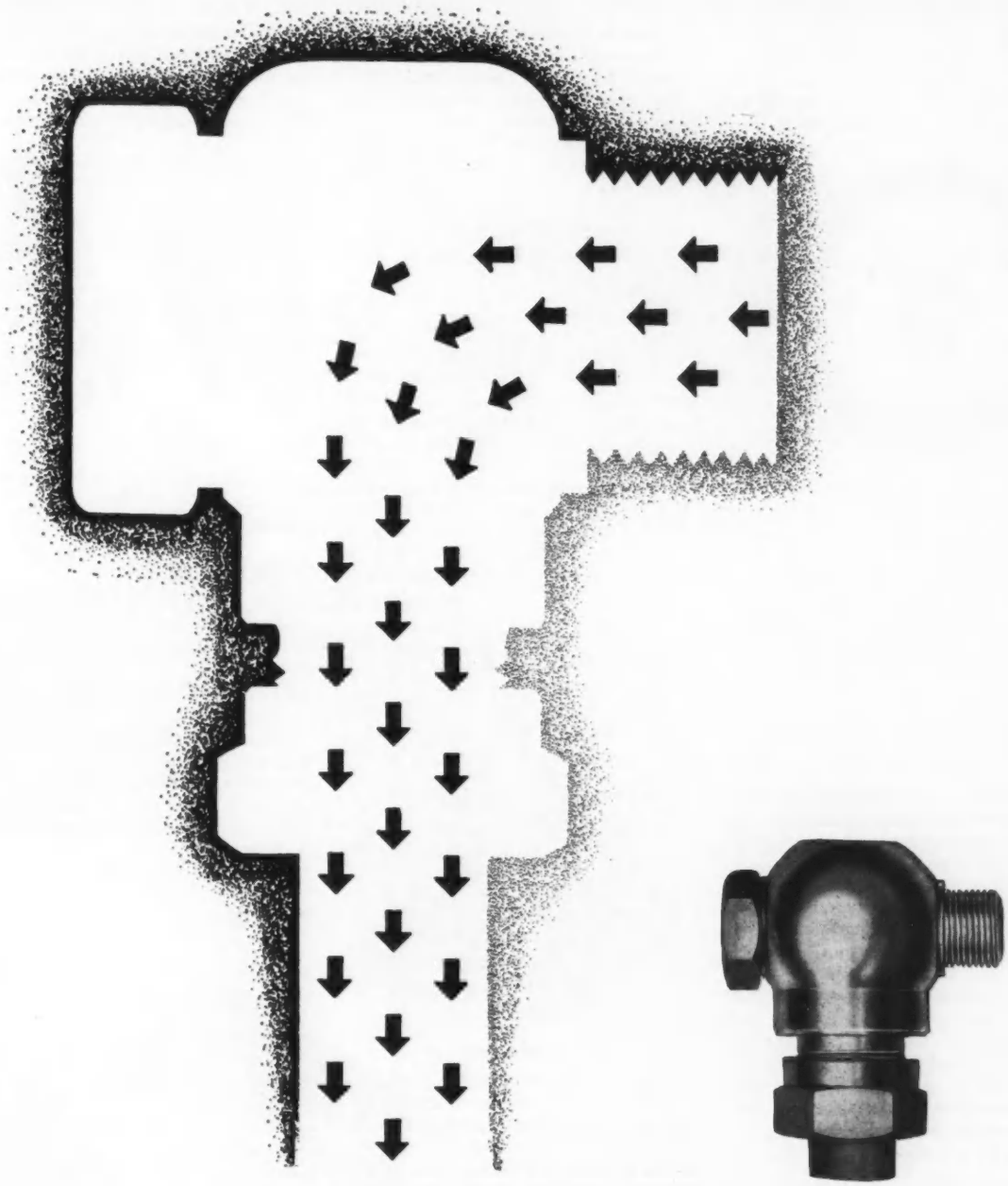
Tick **No 509** on reply card

TEMPERATURE CONTROLLER

first of the Bikini range

The details of the first of the Fielden Bikini range of transistorized instruments has been released. This is a temperature controller with a differential of 0·5°C, high calibration accuracy and long term stability. It is housed in a small meter type case and occupies a panel space of 4½ in. dia. The 9 in. long scale is calibrated directly in degrees Centigrade or Fahrenheit, and the bold pointer is set to the required control temperature by a small knob in the centre of the instrument. A red lamp visible from the sides as well as from the front indicates the control action. Control can be at any temperature between − 200 and + 500°C with a minimum temperature range span of 50°C.

A platinum resistance element is used



in connection with high pressure

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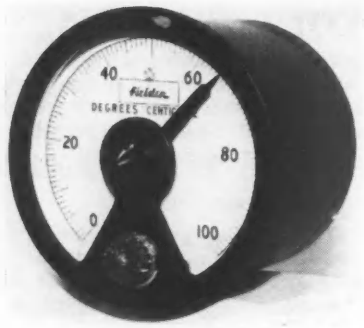
at the temperature measuring point. Ordinary connecting cable is used between the measuring point and the instrument and this can be up to 300 ft in length without introducing errors.



On-off Bikini

The control action is on-off, either electrical or pneumatic. The electrical contacts give change-over switching at 5 A 250 V whilst the pneumatic valve requiries 17 to 20 lb/in² input. The instrument is transistorized and will operate from a 12 V d.c. supply.

Tick **No 510** on reply card

SLIDES

controlling material flow

An improved version of their range of electropneumatically-operated slides for material flow control has been developed by Lindars Automation Ltd.

The units are of fabricated mild-steel construction, and complete with air cylinder, solenoid-operated air valve, open- and closed-position detection switch, and an air release valve for emergency hand operation and maintenance.

Six standard sizes range from 4½ in.sq. to 18 in.sq., and they are available as single units or as part of complete control installations. Special sizes and dust-proof versions are also available.

Tick **No 511** on reply card

BATCH COUNTER

high count rate

A new model, type B.C.P., has been added to the range of batch-counters made by the Electronic Machine Co. Ltd., which can accept up to 10 different programmes at any one time. The maximum counting rate is 2000 counts/s, and the count is displayed on the decade plug-in units by illuminated numerals.

Tick **No 512** on reply card

LOW RIPPLE SUPPLY

with good regulation

A transistor power supply (type TF 1303) has been introduced by Marconi Instrument Ltd. The shunt-stabilized output-voltage is monitored by a built-in large-scale meter and is continuously variable from 2·5 to 24 V. The maximum available output current is dependent upon the voltage being delivered, and varies from 12·5 A at 2·5 V to 0·2 A at 24 V.

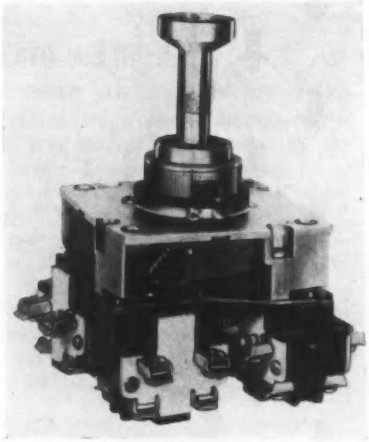
Load regulation of the unit is better than 0·01 V and the ripple content is less than 0·5 mV. It may be operated at ambient temperatures of up to 45°C.

Tick **No 513** on reply card

SWITCH

joy stick type

The joy stick operator (type TX) from Square D Ltd., is four push-buttons in one unit. The joy stick finds its application where it is essential to assure operation of only one push-button at a time. It allows operation in any one of four positions by means of a single lever, and is available as either a momentary or maintained contact operator with or without an off position latch. There is also a mechanism in the handle which requires pressing before movements of



Four-in-one

the operating handle may be made.

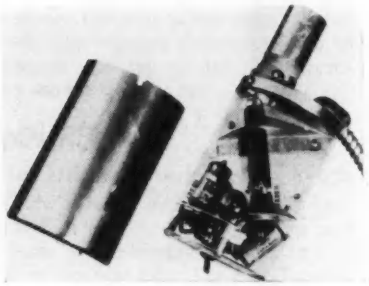
Each operating position of the handle has a correspondingly numbered latch bar. Individual latch bars can be removed allowing the handle to be moved from the centre or off position to the operating position correspondingly numbered without having to depress the release pin (the pin in the handle which operates the off position latch). Any of the operating lever positions can be changed from momentary to maintained contact by moving the lever pin from the 1st to 2nd slot. This conversion can be reversed.

Tick **No 514** on reply card

PHOTOCELL

for ultra-violet only

The Ultravision is a photocell which is activated only by ultra-violet radiation in the wave band 0·2 to 0·26 microns. It is completely insensitive to infra-red and visible radiation, and will therefore not register anything except genuine flames or electric sparks. The cell is available as a complete flame detector incorporating its own heat block and amplifier.



Narrow-band sensitivity

The photocell is made by Honeywell Controls Ltd.

Tick **No 515** on reply card

VIBRATION METER

direct indication

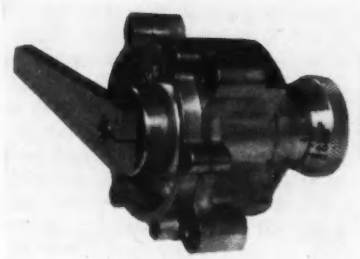
Research and Control Instruments Ltd. have announced the introduction of a direct-reading vibration meter (type PR. 9252). Its features include a wide measuring range and direct-indication in vibration amplitude. It has a transistorized amplifier and is fed from a built-in chargeable miniature battery. There is an additional input for a phase-indicator and an output jack for oscilloscope or recorder.

Tick **No 516** on reply card

DASHPOT

with variable rate

The Kinetrol precision dashpot is now available in an adjustable-rate version. Any numerical value of damping within a 10:1 range may be obtained by setting the calibrated knob to the desired rate. The unique characteristics claimed for this silicone-filled damper are the absence of friction, ensuring purely viscous resistance, and the elimination of leakage and backlash. This is because the shaft



Adjustable damping rate

seal is a flexible rubber sleeve bonded to both the cover and the shaft, and there is no surface at which sliding

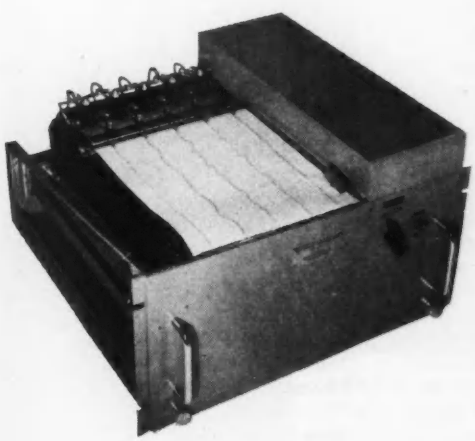
CAPTURE

TRANSIENT PHENOMENA FOR GOOD WITH

KH

High-speed

PEN RECORDERS



Continuous recording of rapid, transient or oscillatory phenomena is made possible with Kelvin Hughes High Speed pen recording instruments. A wide range of instruments is available including new units which will permanently record up to 8 variables simultaneously. When used in conjunction with special Kelvin Hughes bridge amplifiers and power units, the recorders will measure strain, force, displacement, drag, pressure, acceleration and similar variables, providing instantaneous permanent recordings. Rapid response, versatility and dependability make them well suited for research work in aerodynamics, rockets, hydraulics, computers, and countless applications in industry, including civil engineering, mining, production testing of motor cars and tractors.

Ruggedly built and insensitive to external vibrations, Kelvin Hughes pen recorders will operate effectively under the most exacting conditions in vehicles, aircraft, and where heavy industrial plant is operating.

KH

Please write for technical literature. Kelvin Hughes specialists are freely available to advise on any particular application for single- or multi-channel recorders in industry.

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occurs. Rates available are 2–2000 lb in/(rad/s).

A differential rate model is also available which gives a large uni-directional resistance. Delivery is quoted as three days.

Tick **No 517** on reply card

SIGNAL GENERATOR

good long-term stability

The Boonton signal generator (type 225-A) is designed for laboratory use in connexion with the development and testing of receivers and associated circuits in the frequency range from 10 to 500 Mc/s. Short-term (5 min) stability is better than 0·001% and long-term (1 h) stability is better than 0·01%. The change in frequency for a 5 V line change is less than 0·001%. Through the use of a backlash-free precision gear train the radio-frequency output-discrimination is better than 0·05%. Further information is available from Leland Instruments Ltd.

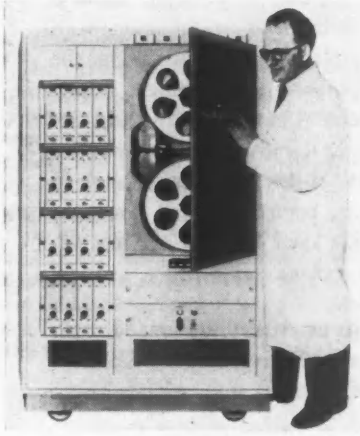
Tick **No 518** on reply card

DATA RECORDER

for industrial use

A standard magnetic tape recorder has been added to the range of equipment made by the Solartron Electronic Group.

The frequency range (analogue mode)



Wide range of tape speeds

is 100 c/s–100 kc/s with a frequency modulation of 0–10 kc/s. The input level is 0·5–25 V r.m.s. with an input impedance of 0·1 MΩ. The tape speeds are 60, 30, 15, 7½, 3¾ and 1⅞ in/sec, with a tape capacity of 5000 ft. The 14 channels can be used with 7 reproducing and 7 recording simultaneously, or with them all recording or reproducing together. The cumulative flutter for frequencies up to 5 kc/s is 0·15% peak-to-peak to 60 in/sec. The signal-noise ratio is 40 dB and the crosstalk is 50 dB down.

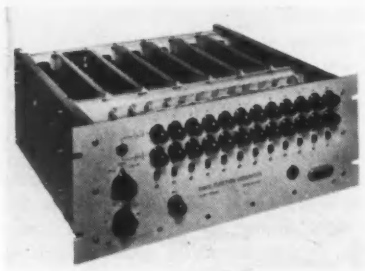
The power required is 1200 W on a 230 V 50 c/s supply. The weight of the recorder is 750 lb and the price is from £4000 to £5000, with a delivery of approximately 3 months.

Tick **No 519** on reply card

FUNCTION GENERATOR

a non-linear accurate unit

The function in the diode function generator (type TR829) is generated in 12 segments; and is set-up by adjusting break-points for each segment against a digital voltmeter monitor. These adjust-



Extra operational amplifiers not required

ments are made on high-resolution helical potentiometers, over the voltage range zero to ± 100 V. It incorporates a total of 14 high-gain d.c. amplifiers and does not require additional operational amplifiers to provide full output. Drift and gain errors for each segment are held inside 100 mV and 0·2% respectively, and since these errors are non-cumulative over the whole function generated, the long-term stability overall is claimed to be better than 0·5% average.

The generator is made by the Solartron Electronic Group and costs £450, with a delivery time of 2–3 months.

Tick **No 520** on reply card

FLOWMETER

of the free impeller type

A flowmeter of the free impeller type has been introduced by Electro-Mechanical Systems Ltd. The rotor is dynamically balanced, and it is claimed that the bearing design is such that end thrust has been entirely eliminated, allowing a high degree of accuracy to be achieved.

The sensing element is a magnetic device separated from the flow of liquid. The output is of sinusoidal form giving two, four or eight pulses per revolution. The calibration characteristic of the rotor sensing element is inherently stable over a wide range of flows. Linearity and accuracy are ± 0·5% from 12 to 100% of rated value.

The construction of the basic flowmeter is in austenitic stainless steel. If required a range of transistorized potted elements is available for coupling to this unit.

Tick **No 521** on reply card

PROFILE MONITOR

will scan up to 3000 c/s

The profile monitor, model 201, can display up to 90 inputs on the face of a 17 in. cathode-ray tube. The inputs appear across the face of the tube in the form of a bar-graph. Though up to 90 inputs can be tackled, 60 is the recommended maximum figure and provides optimum clarity. The time base is 25 cm long and has a frequency of 30 c/s. The input signals are commutated to the profile monitor by a high-speed mercury-jet commutating switch.

The full-scale vertical deflexion is 15 cm and the accuracy is claimed to be ± 2% over this range. The resolution is 40 lines/in. and sensitivity from 0–10 mV to 0–150 V peak-to-peak full scale. Any three consecutive decades in this range will be provided to fit customer requirements.

The maximum scanning rate is 3000 c/s, depending on the commutating

Handles up to 90 inputs

switch used. An alarm is given on any input exceeding a given percentage of full scale output. The alarm dial is calibrated zero to 110% full scale.

The profile monitor is made by the Advanced Technology Laboratories (U.S.A.).

Tick **No 522** on reply card

GALVANOMETER

will accept 26 inputs

A reflecting galvanometer, made by Ruhstrat of Goettinger, is designed for use where a number of different measurements have to be made simultaneously. It has 26 electrically-separate measur-

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ing systems mounted in a magnet block, and a corresponding set of movable mirrors to direct light from a single source to the mirror of each system.

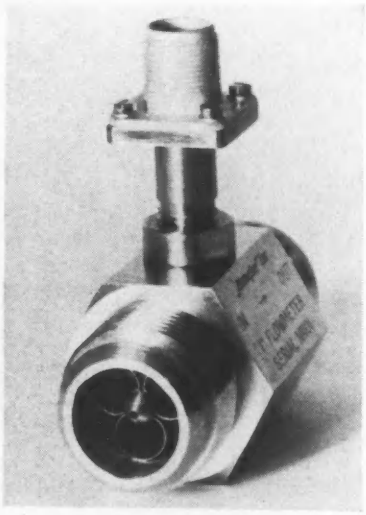
There are eight individual measuring systems available for use in this instrument, ranging in natural frequency from 5 to 700 c/s, with a corresponding sensitivity range of 10 mm/μA to 0·065 mm/μA. The Rugalvo 26 is distributed by British Sarozal.

Tick **No 523** on reply card

FLOWMETER

with accuracy of ¼%

A range of free-impeller flow meters is to be manufactured by Meterflow Ltd., a new subsidiary of S.E. Laboratories. It covers pipe diameters from ¼ to 8 in. and is claimed to be suitable for all corrosive and non-corrosive liquids. Compensation is provided for the cooling effects of liquid oxygen. An accuracy may be obtained better than ¼% over a range of 8:1, with a repeatability of 0·1%. They are suitable for liquid temperatures between −180° and + 200°C.



Rugged construction

Tick **No 524** on reply card

MILLIVOLTMETER

wide frequency-tolerance

The Airmec type 264 meter is intended for the measurement of voltages from 300 μV to 100 V in the frequency range 20 c/s to 10 Mc/s. It consists basically of a wide-band amplifier feeding a rectifying circuit and meter, but input and output sockets have been provided so that the amplifier may be used alone. Under these conditions, a gain of 40 dB may be obtained at up to 10 Mc/s, with a useful response to 20 Mc/s, and a gain of 60 dB is realized at reduced bandwidth.

Tick **No 525** on reply card

SWITCH

non-directional actuation

Square D Ltd. have announced the availability of a wobble-stick operator (type TW-1), which is actuated by pushing the lever in any direction. Because of the method of operation, the wobble stick is claimed to be particularly suited for use as an emergency stop operator on a pendant type station, where it would be desirable to reach the operator quickly from any direction.

Tick **No 526** on reply card

QUICK LOOKS

The TI N2009, one of the new series of standard diffused-junction silicon solar-cells produced by Texas Instruments Inc., provides a typical efficiency of 9% and a spectral emissivity of 0·7 at four microns wavelength illumination, 0·4 at 11 microns. The N2009 cells are capable of 22·5 mW output giving 56·5 mA and 0·4 V per cell when operated under sunlight levels as found in near space.

Tick **No 527** on reply card

A silicon rectifier which will replace the 866 mercury-vapour valve is available from Sarkes Tarzian. Maximum continuous rating of the S-5130 (in a single-phase half-wave circuit) is 300 mA at a peak inverse voltage of 10·4 kV.

Tick **No 528** on reply card

A coupling, intended primarily for electromechanical control circuits, is claimed to give high torsional rigidity. The Metastream 'ES' has stainless steel membranes, and is made by Metaducts in bore sizes from $\frac{1}{16}$ to $\frac{5}{16}$ in., in $\frac{1}{32}$ in. steps.

Tick **No 529** on reply card

A time-code generator providing timing signals during tape-recording of test data is available from Computer-Measurements Co. It has eight separate outputs between 100,000 and 0·01 c/s. The model 1021 generator uses variable pulse-widths to code each timing signal.

Tick **No 530** on reply card

An explosive gas detector is being marketed by I.E.C.-Sieger Ltd. It is claimed to be sensitive to all inflammable gases and to resist vibration. The standard model costs £18 10s. including the detector head and 15 ft of cable.

Tick **No 531** on reply card

Baldwin Industrial Controls have developed a new square miniature moving coil meter. The range covered for direct current can be from 50 μA to 100 A and from 50 mV to 300 V. Alternating current ranges are from 50 μA to 20 A and from 5 V to 300 V.

Tick **No 532** on reply card

Texas Instruments Inc. have developed two silicon mesa transistors (the 2N715 and 2N716) which have a minimum power output of 500 mW at 70 Mc/s. They will deliver about 50 mW at 200 Mc/s.

Tick **No 533** on reply card

Philips stroboscope (type PR.9104) is being marketed by Research and Control Instruments Ltd.

Tick **No 534** on reply card

INDUSTRIAL PUBLICATIONS

Switches and signal lamps—a 60-page booklet from Arcolectric (Switches) Ltd. with prices and part numbers (List No. 132)

Tick **No 535** on reply card

Switches and signal indicator lamps—a 16-page abridged version of List No. 132 from Arcolectric (Switches) (List No. 132/A)

Tick **No 536** on reply card

Distant indication and control—a 7-page booklet from Evershed's about their ohmmeter system (Publication 531).

Tick **No 537** on reply card

Electro-pneumatic converter—a 4-page leaflet from Evershed's on simple proportional action for low air pressures (Publication 532)

Tick **No 538** on reply card

Precise **tank gauges** are explained in a loose-leaf folder from Evershed's entitled 'From Kent to Kuwait, Iraq to Venezuela'

Tick **No 539** on reply card

High-speed counters—two leaflets on counters for industrial control from Mullard Equipment

Tick **No 540** on reply card

Combi-Element and **Norbit** are the titles of two leaflets from Mullard Equipment, on building bricks for industrial control systems and electronic equipment

Tick **No 541** on reply card

Precision Vernier D.C. Potentiometer—leaflets from Doran Instrument Co. (List 119)

Tick **No 542** on reply card

Avel Information—A 35-page booklet produced by Aveley Electric containing information on new developments by Rhode & Schwarz and Gossen, and details of Aveley's specialized production of toroidally wound items.

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Needle bearings—A 4-page publication from I.N.A. Needle Bearings, showing typical sizes and some applications.

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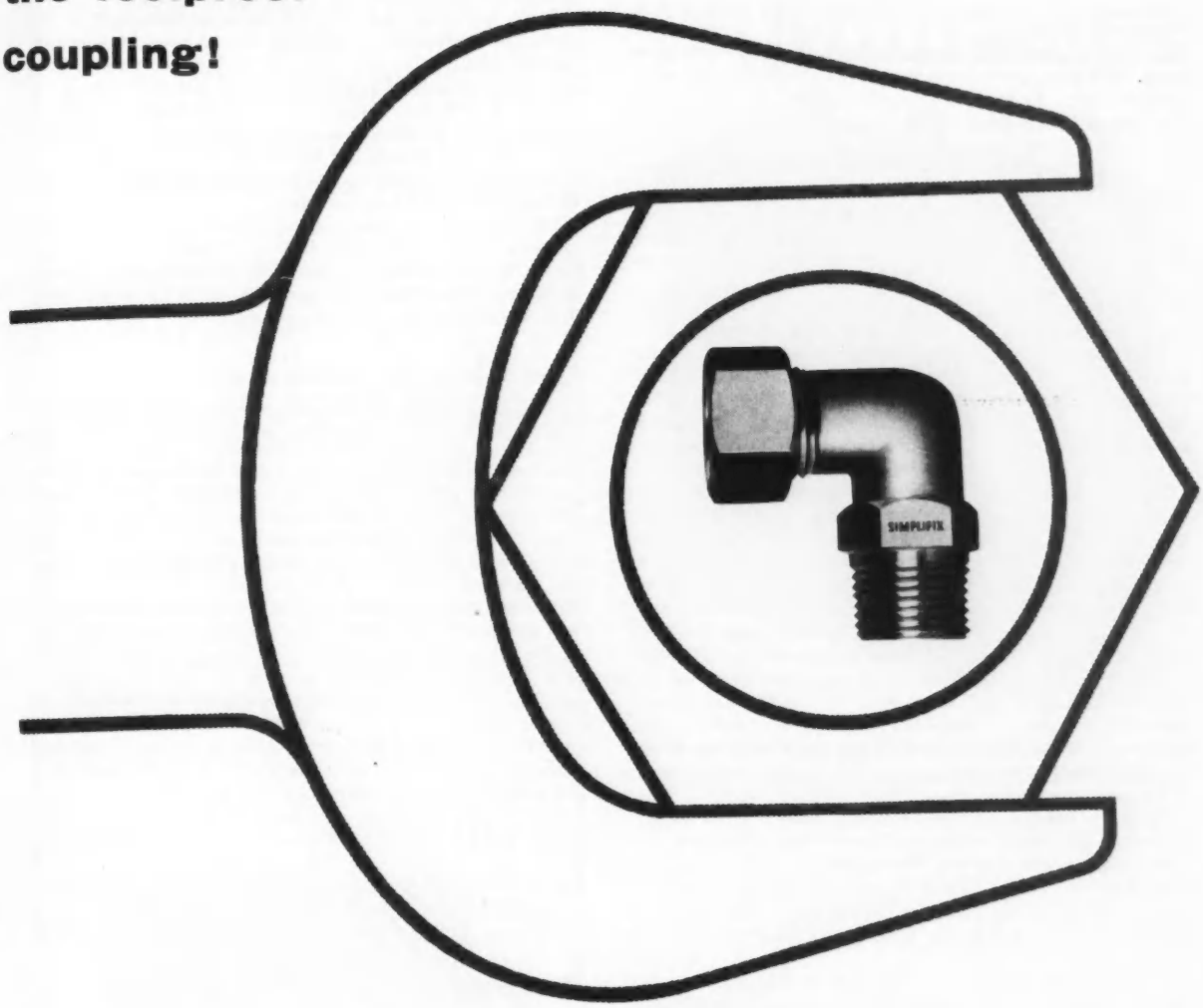

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Book Reviews

Incredibly haphazard

Servomechanism Fundamentals *by* **Ben Zeines.** *McGraw-Hill. 1959. 257 pp. £2 3s.* ★ **701**

The title of this book is identical to that of the very good book by Lauer, Lesnik and Matson but thereafter any comparison ceases. By English standards at least, it is misleading. The object of the book is 'to acquaint the student and the technician . . . with the basic methods of servo systems and data transmission systems.' In some 120 pages servo components are described. Then follow chapters on 'performance improvers' (28 pages), methods of measurement (11 pages) and examples of servo systems (16 pages). Three appendices deal in turn with magnetic amplifiers (steady state only—4 pages), d.c. motors (by Laplace operator—2½ pages) and the theory of servomechanisms (by classical differential equation methods—10 pages).

The chapter contents seem incredibly haphazard. If the hydraulic valve is described on page 41 why include hydraulic motors under a.c. servomechanisms on page 159? The latter chapter also includes gear trains, backlash and two-speed servo drives as if such things never occurred except in a.c. servos.

The use of synchros to produce an error voltage is confused with the synchronous link by the statement (p. 74) that 'the 180° position is usually an unstable position' followed by a reference to the torque on the rotor. As the supply voltage is only connected to one rotor, there is no torque. The use of split gears is restricted to 'light duty servos' with no mention of their use in a measuring loop, with normal gears for load carrying. The characteristics of cross-field machines (all under the single heading 'Amplidynes') are not given and what information there is must be looked for under 'd.c. Servomotors.' The phase and amplitude diagrams for 'performance improvers' (compensating networks and stabilizers) are given but it is difficult to see their value unless the other components in the servo system are dealt with in the same way.

These are but some of the comments which can be made; space does not permit inclusion of even a fair proportion.

The diagrams are clear but some of the photographs are not worth including. Fig. 8.1 (squirrel cage servomotor) is so bad that the details of the rotor are barely visible and those of the stator not at all. Fig. 8.2 might be any small servomotor or generator.

A number of questions are appended to each chapter and the text provides the answers. There are also a few problems but these are of little value as no answers are provided. The bibliography consists of seven book titles, all published in the U.S.A.

G. L. ASHDOWN

O.N.C. but not degree

Electro-Technology for National Certificate Courses *by* **H. Buckingham** *and* **E. M. Price.** *English Universities Press. September 1959. 361 pp. 16s.* ★ **702**

In attempting to increase the sales field of the third volume the authors have failed to satisfy the needs of the degree student and have given too much for the O.N.C. student. This volume of the series more than covers the majority of O.N.C. syllabuses, but fails to achieve its stated object of also covering Applied Electricity for Part I of London University B.Sc.(Eng.) degree; it covers the syllabus content but it does not do it in sufficient detail, nor from fundamental concepts. Many of the explanations lack the incisive clarity which is an essential for the part-time student. The book will be invaluable to any lecturer dealing with O.N.C. and H.N.C. students for its wide subject content and for the many worked examples in the text and the examples, with answers, at the end of each chapter.

It is better to introduce the j operator when a student is thoroughly familiar with the vector solution of a.c. problems, otherwise the physical solution of that problem is meaningless. Volume III does introduce the j operator at a very early stage to solve a.c. problems, before showing the vector solution of a 'compound a.c. circuit'.

While providing numerous references to Volume II of the series the usefulness of the book would have been greatly enhanced had a list of references for further reading been included at the end of each chapter.

The use of L for length in p. 114 might lead to confusion, as this symbol is usually reserved for inductance. The grammar of the sentence starting on line 12 of the paragraph 6.18 is questionable. The answers to the 'percentage and per unit' section of example 8.1 are missing.

The treatment in the chapters headed 'D.C. machines', 'Electric fields', 'Magnetic fields', 'Transformers', 'Circuit theory II', 'Conversion of a.c. to d.c.', 'Electronics', 'Some economic considerations and complex waves', is good, apart from the general criticisms already made.

R. TURNER

Computers for businessmen

Programming Business Computers *by* **Daniel D. McCracken, Harold Weiss** *and* **Tsa Itsai-Hwa Lee.** *Chapman & Hall: London. John Wiley: New York. 1959. 510 pp. £4 2s.* ★ **703**

This large book is claimed to be written for the person who is interested in applying computers to business problems, and who may not have a mathematical background. The authors have a cumulative background which includes training and experience in accounting, systems and procedures, engineering and mathematics. The book is in four parts: (1) the nature of the data processing problem, the central concept of the file, flow charting, and the general characteristics of electronic computers; (2) coding—the coding examples are written in terms of a hypothetical computer which is a compilation of many machines; (3) more advanced topics which are essential to anyone wanting a deeper grasp and a broader background; and (4) a summary of the steps involved in getting a computer application under way, and a critical look at the accounting and auditing problems associated with E.D.P.

It is clearly written, in plain English, is well produced and should prove a valuable reference work. As a textbook it would require much time for study and whether a control engineer who requires a somewhat detailed knowledge of programming business computers would choose this work or a shorter one is a personal matter.

L. LANDON GOODMAN

Books received

Masers *by* **J. Singer.** *Chapman & Hall. 1959. 147 pp. £2 12s* ★ **704**

Impulse-Voltage Testing *by* **W. Hawley.** *Chapman & Hall. 1959. 183 pp. £1 12s* ★ **705**

Laboratory Instruments—their Design and Application *by* **A. Elliott** *and* **J. Home Dickson.** *Chapman & Hall. 1959. 514 pp. £2 15s* ★ **706**

Operational Calculus *by* **Jan Mikusinski.** *Pergamon Press. 1959. 495 pp. £5* ★ **707**

People and Productivity *by* **A. B. Waring.** *British Productivity Council. 1959. 95 pp. £1 5s* ★ **708**

Digital and Sampled-Data Control Systems *by* **Julius T. Tou.** *McGraw-Hill. 1959. 631 pp. £5 16s 6d* ★ **709**

Handbook of Electronic Control Circuits *by* **J. Markus.** *McGraw-Hill. 1959. 347 pp. £3 6s* ★ **710**

Handbook of Automation, Computation and Control: Vol. 2. Computers and Data Processing *by* **E. M. Grabbe, S. Ramo** *and* **D. E. Wooldridge.** *Chapman & Hall: London. John Wiley: New York. 1959. 1071 pp. £7* ★ **711**

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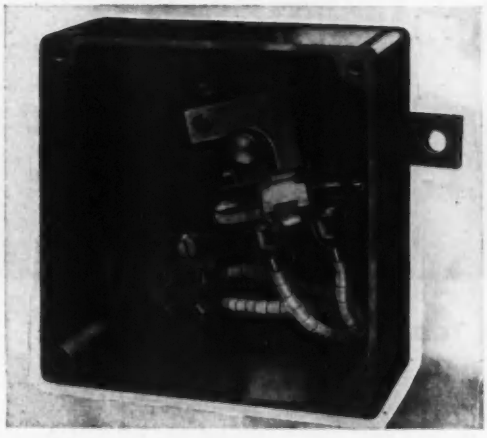

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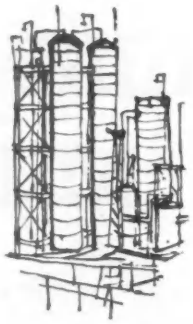

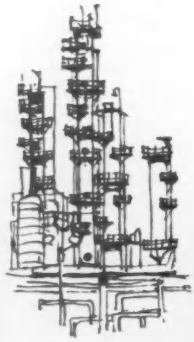

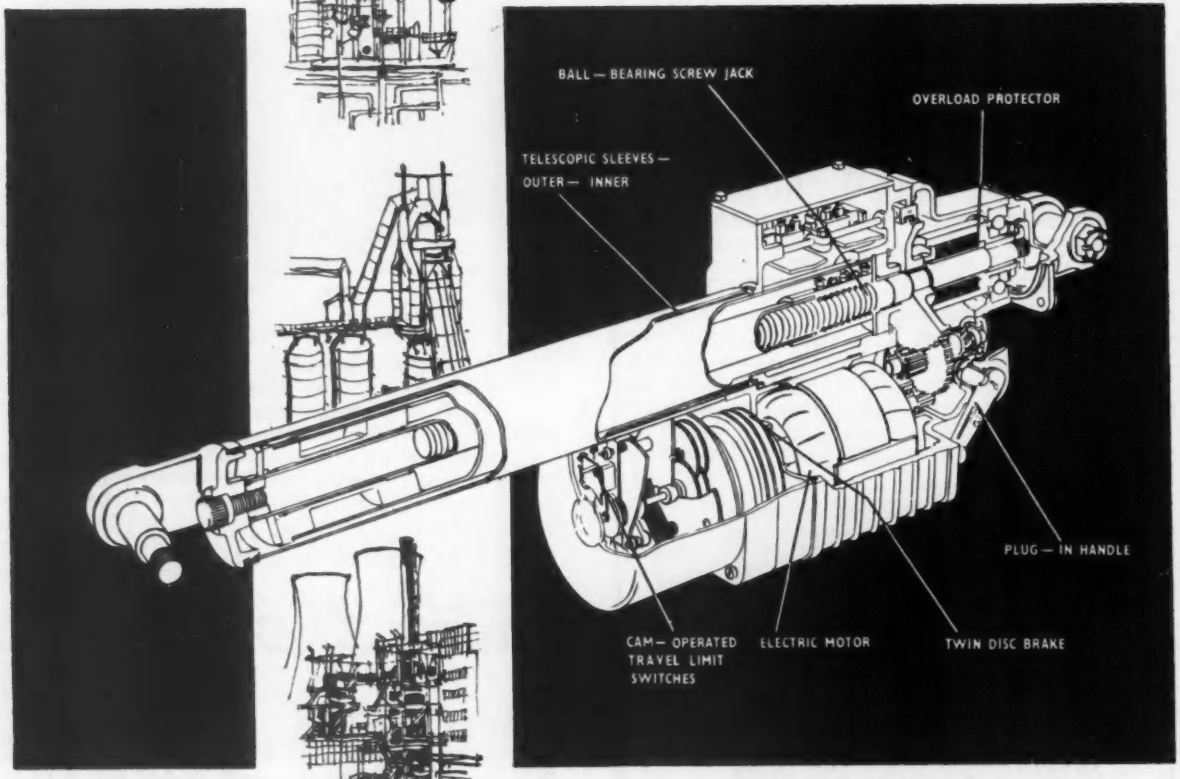
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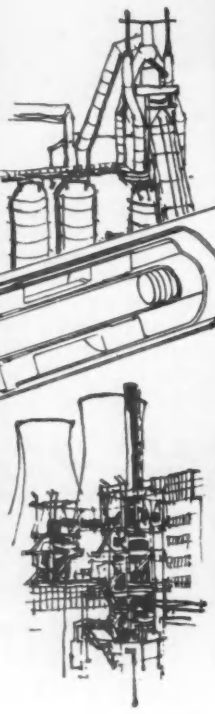

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